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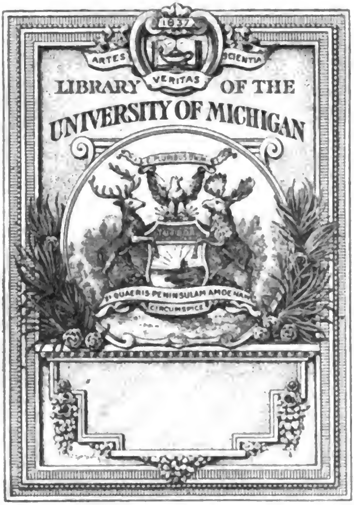
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REPORT

OF THE

THIRTIETH MEETING

OF THE

BRITISH ASSOCIATION

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FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT OXFORD IN JUNE AND JULY 1860.

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OBJECTS.

The Association contemplates no interference with the ground occupied by other Institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another, and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

ADMISSION OF MEMBERS AND ASSOCIATES.

All Persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions, shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee, shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

COMPOSITIONS, SUBSCRIPTIONS, AND PRIVILEGES.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

Associates for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.

2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.

3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]

4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]

5. Associates for the year, subject to the payment of One Pound.

6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members, who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than* 100 *copies remain*, at one-third of the Publication Price. Application to be made (by letter) to Messrs. Taylor & Francis, Red Lion Court, Fleet St., London.

Subscriptions shall be received by the Treasurer or Secretaries.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

1. Presidents and Officers for the present and preceding years, with authors of Reports in the Transactions of the Association.

2. Members who have communicated any Paper to a Philosophical Society, which has been printed in its Transactions, and which relates to such subjects as are taken into consideration at the Sectional Meetings of the Association.

3. Office-bearers for the time being, or Delegates, altogether not exceeding three in number, from any Philosophical Society publishing Transactions.

4. Office-bearers for the time being, or Delegates, not exceeding three, from Philosophical Institutions established in the place of Meeting, or in any place where the Association has formerly met.

5. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing for the Meeting of the year by the President and General Secretaries.

6. The Presidents, Vice-Presidents, and Secretaries of the Sections are *ex-officio* members of the General Committee for the time being.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects, shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee, unless previously recommended by the Committee of Recommendations.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer, shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

I. Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. York, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. Oxford, June 19, 1832.	Sir David Brewster, F.R.S.L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. Cambridge, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MAKDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. Edinburgh, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. Dublin, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. Bristol, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London Liverpool, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. Newcastle-on-Tyne, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. Birmingham, August 26, 1839.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. Glasgow, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount Edgecumbe.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. Plymouth, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir D. T. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. Manchester, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.

The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	Earl of Listowel. Viscount Adare. Sir W. R. Hamilton, Pres.R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. Professor Powell, F.R.S.	Henry Clark, M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. DelaBeche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's.	Matthew Moggridge, Esq. D. Nicol, M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews. EDINBURGH, July 31, 1850.	Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S.L. & Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal. IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich. Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, M.R.I.A., Pres. R.S. Sir Henry T. DelaBeche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., & Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Philos. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, M.D., V.P. Hull. Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S.L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, M.D., F.R.S. Thomas Inman, M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, LL.D. Prof. Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugall, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Honourable the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Prof. Jellett, F.T.C.D. W. Neilson Hancock, LL.D.

RICHARD OWEN, M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen. Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen.	Prof. J. Nicol, F.R.S.E., F.G.S. Prof. Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford. The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, M.A., Esq. Prof. H. E. Roscoe, B.A.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from 14th September 1859 (commencement of ABERDEEN MEETING) to 27th June 1860 (at OXFORD).

RECEIPTS.

	£	s.	d.	£	s.	d.
To Balance brought forward from last Account				199	7	10
Life Compositions at Aberdeen and since				299	0	0
Annual Subscriptions, ditto ditto				600	2	0
Associates' Tickets, ditto ditto				1206	0	0
Ladies' Tickets, ditto ditto				821	0	0
6 Months' Dividends on £6000 3 per cent. Stock				85	2	6
Interest on Cash from Bank at Aberdeen				14	2	9
From the Sale of Publications—						
viz. For Reports of Meetings	136	19	1			
Catalogues of Stars, and Dove's Lines	32	3	0			
				169	2	1
				£3393	17	2

Examined and found correct.

ROBERT HUTTON,
NORTON SHAW,
J. P. GASSIOT,
} *Auditors.*

PAYMENTS.

	£	s.	d.	£	s.	d.
By Expenses of Aberdeen Meeting, Sundry Printing, Binding Reports, Advertising, and Incidental Payments by the General Treasurer and the Local Treasurers				465	7	9
Printing Report of the Twenty-eighth Meeting	£574	13	9			
Engraving, &c. of the Twenty-ninth Meeting	41	11	0			
				616	4	9
Salaries, 12 months				350	0	0
Subscriptions returned as per Resolution of the Council:—						
Sir Thomas Gladstone	£1	0	0			
Mr. Dyce Nicol	1	0	0			
				2	0	0
Purchase of £500 3 per cent. Consols				474	7	6
Maintaining the Establishment of Kew Observatory				500	0	0
Dredging near Belfast				16	6	0
Dredging in Dublin Bay				15	0	0
Inquiry into the Performance of Steam-vessels				124	0	0
Explorations in the Yellow Sandstone of Dura Den				20	0	0
Chemico-mechanical Analysis of Rocks and Minerals				25	0	0
Researches on the Growth of Plants				10	0	0
Researches on the Solubility of Salts				30	0	0
Researches on the Constituents of Manures				25	0	0
Balance of Captive Balloon Accounts				1	13	6
Balance at the Bankers	£698	13	6			
Ditto in hand of the General Treasurer and Local Treasurers	20	4	2			
				718	17	8
				£3393	17	2

II. Table showing the Names of Members of the British Association who have served on the Council in former years.

Aberdeen, Earl of, LL.D., K.G., K.T., F.R.S. (dec^{d}).
Acland, Sir Thomas D., Bart., F.R.S.
Acland, Professor H. W., M.D., F.R.S.
Adams, J. Couch, M.A., F.R.S.
Adamson, John, Esq., F.L.S.
Ainslie, Rev. Gilbert, D.D., Master of Pembroke Hall, Cambridge.
Airy, G. B., D.C.L., F.R.S., Astronomer Royal.
Alison, Professor W. P., M.D., F.R.S.E. (dec^{d}).
Allen, W. J. C., Esq.
Anderson, Prof. Thomas, M.D.
Ansted, Professor D. T., M.A., F.R.S.
Argyll, George Douglas, Duke of, F.R.S.
Arnott, Neil, M.D., F.R.S.
Ashburton, William Bingham, Lord, D.C.L.
Atkinson, Rt. Hon. R., Lord Mayor of Dublin.
Babbage, Charles, Esq., M.A., F.R.S.
Babington, Professor C. C., M.A., F.R.S.
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Report of the Council of the British Association, presented to the General Committee at Oxford, June 27, 1860.

1. The Council were instructed by the General Committee at Aberdeen to maintain the establishment at Kew Observatory by aid of a grant of £500. They have received the following Report of the Committee to whom the working of the Observatory is entrusted.

2. The continuance of Magnetic Observations, at stations indicated by the General Committee at the Leeds Meeting, has engaged the attention of H.R.H. the President, and of the Council; and they have had the advantage of cooperation on the part of the President and Council of the Royal Society. Every means has been adopted for pressing the subject on the favourable attention of the Government, but, it is to be regretted, hitherto without success.

3. The importance of telegraphic communication between sea-ports of the British Isles, has been the subject of much attention since it was urged on the General Committee by the Aberdeen Meeting. The Council are happy to find that Admiral FitzRoy has been authorized to proceed in bringing to a practical issue the recommendations offered on this subject to the scientific department of the Board of Trade; and they congratulate the Association on the share they have taken in a cause so dear to humanity.

4. The expedition suggested by the Royal Geographical Society, and concurred in by the General Committee of the British Association, is on its way; Capt. Speke, under the direction of the Admiralty, with his assistant, Capt. Grant, having sailed from Zanzibar. Sir R. I. Murchison, in reporting on this subject, expresses the obligation which is felt by the promoters of this great step for the exploration of Africa, to Lord John Russell, Secretary of State for Foreign Affairs.

The Report of the Parliamentary Committee is received for presentation to the General Committee this day.

5. At the Meeting this day, in pursuance of the Notice placed in the Minutes of the General Committee at Aberdeen, it will be proposed—"That a permanent distinct Section of Anatomy and Physiology be established, in addition to that of Zoology and Botany."

The Council are informed that Invitations will be presented to the General Committee at its Meeting on Monday, July 2, to hold the next Meeting in Manchester; on behalf of the Literary and Philosophical Society of Manchester, and other Institutions and Public Authorities of that city, from whom Invitations were received at previous Meetings.

Invitations will also be presented to hold an early Meeting in Newcastle, on behalf of the Council and Borough of Newcastle-upon-Tyne, and to hold a Meeting in Birmingham in 1862, on behalf of the Birmingham and Midland Institute.

Report of the Kew Committee of the British Association for the Advancement of Science for 1859–1860.

Since the last Meeting of the British Association, the self-recording magnetographs have been in constant operation under the able superintendence of Mr. Chambers, the magnetical assistant.

A description of these instruments has been given by Mr. Stewart, the Superintendent, in a Report which is printed in the Transactions of the British Association for 1859. The drawings for the plates connected with this Report were made with much skill by Mr. Beckley, the mechanical assistant at Kew.

It was mentioned in the last Report of this Committee, that a set of self-recording magnetic instruments, designed for the first of the Colonial Observatories which have been proposed to Her Majesty's Government, had been completed and set up in a wooden house near the Observatory.

Shortly after the meeting at Aberdeen, the Chairman received a letter from Dr. P. A. Bergsma, Geographical Engineer for the Dutch possessions in the

Indian Archipelago, requesting that the Committee would assist him in procuring a set of self-recording magnetic differential instruments similar to those at Kew, the Dutch Government having resolved to erect such at their Observatory at Java.

In consequence of this application, and as the instruments which had been completed were not immediately required for a British Observatory, it was resolved that they should be assigned to Dr. Bergsma; this gentleman has since arrived, and has for the last few weeks been engaged at the Observatory in the examination of his instruments.

The usual monthly absolute determinations of the magnetic elements continue to be made.

Application having been made through Padre Secchi, of the Collegio Romano, for a set of magnetic instruments, for both differential and absolute determinations, for the Jesuits' College at Havanna, the whole to cost 600 dollars, or about £150, General Sabine obtained, at a reasonable price, the three magnetometers that had formerly been employed at Sir T. Brisbane's Observatory at Makerstoun, and also an altitude and azimuth instrument. With these instruments it is expected that the application from Havanna Observatory can be met within the sum named; the instruments are now in the hands of the workmen, and will be ready early in July.

Two unifilars, supplied by the late Mr. Jones, for the Dutch Government (one for Dr. Bergsma, and the other for Dr. Buys Ballot), have had their constants determined. Observations have also been made with two 9-inch dip-circles belonging to General Sabine, which have been repaired by Barrow, and with two dip-circles and a Fox's instrument designed for Dr. Bergsma.

A set of magnetical instruments, consisting of a dip-circle, an azimuth compass, and a unifilar, previously used by Captain Blakiston, have been re-examined, and have been taken by Colonel Smythe, of the Royal Artillery, to the Feejee Islands.

As it was feared that the Kew Standard Barometer might have been injured by the workmen who some time since were repairing the Observatory, a new one has been mounted. The mechanical arrangements of this instrument have been completed in a very admirable manner by Mr. Beckley; and the mean of all the observations made shows that the new Barometer reads precisely the same as the old. This result is satisfactory, not only as showing that no change has taken place in the old Barometer, but as confirming the accuracy of the late Mr. Welsh's process of constructing these instruments. The height of the cistern of the new Barometer above the level of the sea is 33·74 feet.

Mr. Valentine Magrath having quitted the Observatory, at his own request, on the 14th of February last, Mr. George Whipple has taken his place as Meteorological Assistant, and has given much satisfaction.

On the 12th of March, Thomas Baker was engaged at the weekly salary of 8*s*., to be raised to 10*s*. in six months if he gave satisfaction, which has hitherto been the case.

Since the last meeting of the Association, 173 Barometers and 222 Thermometers have been verified at the Observatory.

Professor Kupffer, Director of the Russian Magnetical and Meteorological Observatories, visited the Observatory, and was presented with a standard thermometer.

Mr. J. C. Jackson, Lieutenant Goodall, R.E., and Mr. Francis Galton, F.R.S., have visited the Observatory, and received instructions in the manipulation of instruments.

Mr. Galton has made some experiments at Kew Observatory, to determine the most practicable method of examining sextants, and other instruments for geographical purposes. Considering that these instruments, after having been once adjusted, are liable to two distinct classes of error, the one *constant* for any given reading, and the other *variable*, it is an object to form Tables of Corrections for the constant errors of instruments sent for examination, and also to ascertain the amount of variable errors which might affect their readings.

As a groundwork for examination, it is found that small mirrors may be permanently adjusted, at the distance of half a mile, so that when the rays of a mirror of moderate size, standing by the side of an assistant, are flashed upon them, they may re-reflect a brilliant star of solar light, towards the sextant under examination.

By having four permanently fixed mirrors of this description, separated by intervals of 20°, 60°, and 40° respectively, and by flashing upon them with two looking-glasses of moderate size, it is possible, by using every combination of these angles, to measure every twentieth degree, from 0° up to 120°.

The disturbing effects of parallax are eliminated without difficulty, by mere attention to the way in which the sextant is laid on the table, or, in the case of a zero determination, by a simple calculation.

Moreover, the brilliancy of the permanent mirrors is perfectly under control, by the interposition of gauze shades in front of the looking-glasses that flash upon them. This renders an examination of the coloured shades a matter of great ease and certainty.

Based upon these principles, Mr. Galton has drawn up a system for the thorough examination of sextants. Each would not occupy more than two hours in having its constant errors tabulated, and its variable errors determined; nor would an outlay of more than £30 be required for the establishment of fixed tables and permanent marks. Difficulty is, however, felt in setting the system in action, owing to the absolute need of an assistant having leisure to undertake it.

The sum of £179 12*s*. 6*d*. has been received from the Royal Society, to defray the expense of erecting a model house for the reception of the instruments for Colonial Magnetic Observatories.

The Photoheliograph has been an occasional source of occupation to the mechanical assistant; but before daily records of the sun's disk can be obtained, it is absolutely requisite that an assistant should be appointed to aid Mr. Beckley, because his duties are of such a nature as to prevent his devoting attention at fixed periods of the day to an object requiring so much preparation as is the case with photoheliography. Unfortunately, the funds at the disposal of the Committee are quite inadequate for this purpose; and unless a special grant be obtained, the Photoheliograph will remain very little used.

At present Mr. Beckley is preparing the instrument, under Mr. De la Rue's direction, for its intended trip to Spain, for the purpose of photographing the eclipse which takes place on July 18th. The expenses of these preparations, and of the assistants who will accompany Mr. De la Rue, will be defrayed out of the grant of the Royal Society for that object.

The requisite preparations are somewhat extensive; for it has been deemed necessary to construct a wooden observatory, and to make a new iron pillar to support the instrument, adapted to the latitude of the proposed station: both the observatory and iron pillar may be taken to pieces to facilitate their transport.

The wooden house is 8 feet 6 inches square, and 7 feet high; it is entirely open at the top, except that portion divided off for a photographic room.

The open roof will be covered by canvas when the observatory is not in use; and when in use, the canvas will be drawn back, so as to form an outer casing at some little distance from the wall of the photographic room; and, in order to keep this room as cool as possible, the canvas will, in case of need, be kept wetted.

The chemicals and chemical apparatus will be packed in duplicate sets, so as to provide as far as possible against the contingency of loss, by breakage or otherwise, of a part of them.

Mr. Downes, of the firm of Cundall and Downes of Bond Street, has promised to accompany the expedition; Mr. Beckley will also go; and Mr. De la Rue has engaged Mr. Reynolds to assist in the erection of the observatory in Spain, and in the subsequent photographic operations.

The Admiralty, on the representation of the Astronomer Royal, have provided a steam-ship to convey this and other astronomical expeditions to Bilbao and Santander. It is proposed that the Kew party should land at Bilbao and proceed to Miranda. Mr. Vignoles, who is constructing the Tudela and Bilbao railway, has kindly promised his aid and that of his staff of assistants, to promote the objects of the expedition, and promises, on behalf of the contractors, the use of horses and carts for the conveyance of the apparatus. The expedition will sail from Portsmouth on the 7th of July; and, should the weather prove favourable, there is reasonable hope that the various phases of the eclipse will be successfully photographed. Whether the light of the corona and red prominences will be sufficiently bright to impress their images, when magnified to four inches in diameter, is a problem to be solved only by direct experiment.

Professor William Thomson (of Glasgow) having expressed a desire that the practical utility of his self-recording electrometer should be tried at Kew, his wish has been acceded to and the instrument received, and it is expected that it will shortly be in operation under his direction.

A Report has been completed by the Superintendent on the results of the Magnetic Survey of Scotland and the adjacent islands in the years 1857 and 1858, undertaken by the late Mr. Welsh. This Report is printed in the Transactions of the British Association for 1859.

The following correspondence has taken place between General Sabine and the Rev. William Scott, Director of the Sydney Observatory:—

"Observatory, Sydney, March 2, 1860.

"Sir,—The great interest which you take in the promotion of Magnetical Science encourages me to address you on the subject of the establishment of a Magnetical Observatory at Sydney. The report which I send you by this mail will explain to you the character and position of the Astronomical Observatory under my direction.

"I am convinced that an application to our Government, from influential persons at home, for the establishment of magnetical observations on not too expensive a scale, would be readily attended to. I am not practically acquainted with any magnetical observatory, with the exception of that at Greenwich, and am ignorant of the cost of a set of instruments, and the exact amount of space required for working them; but I believe we could find sufficient room in the observatory without any additional building; they would be under my own supervision, and all that would be required would be an additional assistant, to share with myself and my one assistant in observing and computing. The Governor-General, Sir W. Denison, would, though powerless as regards public money, exert his influence in favour of such an object.

"Trusting that you will take the matter into consideration, and excuse the liberty I have taken in addressing you,

"I am, Sir,
"Your obedient Servant,
(Signed) "W. Scott,
"Astronomer for N. S. Wales."

"*Major-General Sabine.*"

"13 Ashley Place, London, May 8, 1860.

"Sir,—I lose no time in replying to your letter of March 2, received this day. The self-recording magnetical instruments at Kew have been in action nearly two and a half years—a sufficient time to test their merits or defects. I have myself completed the analysis and reduction of the first two years (1858 and 1859) of the Observations of the Declinometer, and can therefore speak of my own knowledge of their performance, as far as that element is concerned. The Photographic Traces, recording both the zero line and the actual movements of the magnet, can be measured with tolerable confidence to the third place of decimals of an inch, the inch in the Kew instrument being equivalent to 22 minutes of arc. The reading is consequently made to the 1000th part of 22 minutes of declination. The record is of course continuous; but, for the purpose of computing the results, *hourly* readings have been tabulated. In the first year the trace failed in 107 out of 8760 hours, chiefly from failure in the supply of gas, which is brought by pipes from Richmond, a considerable distance off. This inconvenience has been remedied by the construction at the Observatory itself, at a small expense, of a water regulator, through which the supply from Richmond passes, and there is now no reason why the trace should ever fail. I have now in course of analysis and reduction the same years of the observations of the horizontal and vertical force magnetographs, and have no reason hitherto to believe that the record of those two elements will be inferior to that of the declination. The three instruments, with the clock which keeps the registering papers in revolution, together with reading telescopes placed for eye observation, either to accompany or to be independent of self-registry, occupy an interior space of about 16 feet by 12, including a passage round for the observer. The cost of such a set of instruments, complete in every respect, is £250; and four months must be allowed for making them from the date of the order, as well as an additional month for their careful verification at Kew (should that be desired), where a detached building has been erected for this particular purpose, in which they may be kept in work in comparison with the Kew instruments. A detailed description of these instruments is now in the press, and will be published in June in the volume of Reports of the British Association. The results of the first two years of the Declinometer observations, showing what are deemed at present to be the most useful modes of eliciting the results, will be printed in the 'Proceedings of the Royal Society' in the present summer, and the first two years of the horizontal and vertical force magnetographs in the same publication later in the year. A small adjoining room is requisite, opening if possible into the instrument-room, which should contain suitable troughs for the preparation of the paper to receive the traces, and to fix them. It is important to diminish as much as possible the changes of temperature in the Observatory itself, exclusive of the effect of the instrument cases, which have adaptations for that purpose. So far in regard to differential instruments. For absolute determinations and secular changes a small detached house is required, say 12 feet by 8, in which equality of temperature need not be regarded, but which must be at a sufficient distance from other buildings containing iron, and have copper fittings. The instruments required for these purposes are an inclinometer and a unifilar, the latter having provision for the experiments of deflection and vibration, as well as for the absolute declination: the cost of the first is £30, and of the second £45; both may be verified, if desired, at Kew. The little work which is sent to you by the same post as this letter contains a full description of these instruments, and directions for their use. In addition to the charges named above, making in all £325, the cost of packing, freight, and insurance will have to be taken into the account.

"One assistant will suffice, as you suggest, for keeping the magnetometers in action, and for tabulation. The absolute values, and the calculation of the results of all the instruments, would be, I presume, the work of the Director of the Observatory himself. Provision must also be made for a supply of chemicals, stationery, and gas. Should it be thought desirable that the instruments should be prepared and verified under the superintendence of the Committee of the Kew Observatory, a request to that effect, transmitted by yourself through the Governor of the Colony to the Chairman of the Committee of the Kew Observatory, Richmond Park, London, S.W., would, I am sure, meet immediate attention. That such an institution at the head-quarters of our Australian dominions would be as honourable to those who should be instrumental in its establishment as it would be beneficial to magnetical science, must be a matter of general recognition, and it would, I am persuaded, find a warm supporter in your present most excellent Governor.

"I remain, Sir,
"Your obedient Servant,
(Signed) "EDWARD SABINE."

"*The Rev. W. Scott.*"

From the following correspondence which has taken place between Her Majesty's Government and the President of the Royal Society, it will be seen that the establishment of a Magnetical Observatory at Vancouver Island is postponed, in consequence of the war with China precluding the establishment at present of a corresponding observatory at Pekin:—

"Treasury Chambers, 16th May, 1860.

"SIR,—I am directed by the Lords Commissioners of Her Majesty's Treasury to acquaint you that My Lords have had under their further consideration the establishment of an Observatory at Vancouver Island, and the insertion in the Estimates of this year of a vote for that service.

"My Lords are fully sensible of the importance of obtaining a series of accurate Magnetical Observations at the stations recommended by the Council of the British Association, and it would give them great pleasure to assist without further delay in forwarding objects so interesting for the cause of science.

"The numerous and pressing claims, however, on the public finances in the present year make it imperative upon My Lords to submit no fresh estimate to Parliament which is not of a very urgent character, and where the total limit of expense to be incurred has not been accurately ascertained.

"In the present instance My Lords must observe that you appear to be under some misapprehension in supposing that any engagement was entered into by the late Government to establish a Magnetic Observatory at Pekin or elsewhere. On the contrary, the letter of this Board of 6th December, 1858, to Lord Wrottesley states that, 'whatever may be the public advantages to be derived from the proposed new establishments, the object would not, it appears, be sacrificed by postponement, and, looking to the extent of the other claims upon the public finances already existing, My Lords have thought it right to defer the consideration of the question until next year.'

"The letter then further states, that the three Magnetical Observatories at the Cape of Good Hope, St. Helena, and Toronto, which were originally sanctioned in an estimate of about £3000 for three years, had in fact cost £11,000 for that period, and, in all, had put the country to an expense of nearly £50,000. This consideration alone suffices to show the necessity for very careful investigation by the Government before any step is taken which might commit the country to further expense. The circumstances referred to in the letter in question continue in full force; and an important further argument against undertaking the proposed Observatory at Vancouver Island at the present moment is furnished by the political events which have since occurred in China. In General Sabine's able letter of the 1st January, 1859, it is stated that, 'without entering into the comparative scientific value of Vancouver Island and Pekin as magnetic stations,—both being highly important,—this much is certain, that, whatever might be the value of either, that value would be greatly enhanced—far more than doubled—by there being a simultaneous and continuous record at both stations; and Sir John Herschel remarks that the importance of a five years' series of observations at one of the proposed stations without the others would be grievously diminished, and the general scope of the project defeated.'

"As the present state of things in China precludes the establishment of a Magnetic Observatory at Pekin, or any point in the Chinese Empire sufficiently to the north to correspond with a station at Vancouver Island (though there is reason to hope that this state of things may be of short duration), it would appear desirable even in the interests of science to postpone the consideration until something more certain can be ascertained as to the possibility of meeting what Sir John Herschel and General Sabine consider such an essential requisite, viz. the commencement and continuance of simultaneous observations at Vancouver Island and at a point in China nearly in the same parallel of latitude. The interval which must elapse until the political state of affairs in China may render such an establishment possible may be usefully employed in obtaining the most accurate estimate possible of the actual cost of founding and maintaining each station for the period requisite for the complete attainment of the scientific objects in view, so as to enable Her Majesty's Government, when the proper time shall arrive, if they shall decide on doing so, to submit a vote to Parliament with confidence as to the amount of expense which they may ask the nation to defray in the interests of science.

"I am, Sir,
"Your obedient Servant,
(Signed) "GEO. A. HAMILTON."

"*The President of the Royal Society.*"

"May 23rd, 1860.

"MY DEAR SIR,—In Mr. Hamilton's letter (returned herewith) he has referred to Sir Charles Trevelyan's communication to Lord Wrottesley of the 6th December, 1858, expressing the desire of the Lords Commissioners of the Treasury to postpone to the following year the consideration of the establishment of the Colonial Magnetic Observatories which had been recommended by the Royal Society and the British Association for the Advancement of Science; but Mr. Hamilton has omitted altogether to refer to the interview which took place between the President of the British Association and Sir Charles Trevelyan subsequent to that communication, viz. on the 18th of December, 1858, when Sir Charles Trevelyan stated that 'if a single station for magnetical and meteorological observations were applied for [intimating Pekin as its locality] by the Joint Committee of the Royal Society and the British Association, My Lords would be disposed to comply with such application.' (See Report of the Council of the British Association, September 1859.)

"Political events which became known shortly after that interview made it manifestly unadvisable to apply for a station in China; but the scientific importance of procuring systematic magnetical researches at other stations which had been named in the original application from two Societies, in parts of the globe which were conveniently accessible and under British dominion, remained as before. In these respects Vancouver Island was unobjectionable, and was therefore substituted for 'a station in China' in the application, which, consistently with Sir Charles Trevelyan's communication of the 18th December, 1858, was made by the Joint Committee of the two Societies. The confident expectations thus founded being known in the United States by the publications of the Reports of the Joint Committee of the Royal Society and British Association, the Government of the United States authorized the establishment of Magnetical Observatories at a station on the east side of the United States, and at another on the south coast, both designed to cooperate with the British Observatory to be established on Vancouver Island; the three stations being obviously remarkably well selected for systematic researches over that large portion of the globe. The two observatories of the United States' Government have been established, and commenced their work at the beginning of the present year.

"In reference to the aggregate amount of expenditure incurred by the magnetical researches recommended to Government by the Royal Society and British Association in the last twenty years, it may be remarked that, the researches being altogether of a novel character, the continuance of the Observatories, when first asked for in 1839, was for a very limited period. It was, in fact, an experiment, and their longer continuance would not have been recommended had not the experiment proved eminently successful, and such as to justify the prosecution of the researches. The subject was therefore brought afresh under the consideration of Government in 1845 and again in 1849, and the further expenditure to be incurred received the sanction of the Treasury on both occasions, as have also, on other occasions, the magnetic surveys connected with the Observatories. It is possible that the aggregate amount of expenditure thus sanctioned and incurred may not be overstated at £50,000. It is an average amount not exceeding £2500 a year for this great branch of physical science.

"I am not myself the proper authority to say whether the gain to science, and to the estimation in scientific respects in which this country is held by other nations, be, or be not, an equivalent for this expenditure; but I may be permitted to refer to the opinion expressed by the Joint Committee of the two Societies, consisting, as is well known, of persons holding high places in public estimation for their general knowledge and good judgment, as well as possessing the highest scientific eminence:—'Your Committee, looking at this long catalogue of distinct and positive conclusions already obtained, feel themselves fully borne out in considering that the operation, in a scientific point of view, has proved, so far, eminently remunerative and successful, and that its results have fully equalled in importance and value, as real accessions to our knowledge, any anticipations which could reasonably have been formed at the commencement of the inquiry.'

"Believe me, my dear Sir,
"Faithfully yours,
(Signed) "EDWARD SABINE."

"*Sir B. C. Brodie, Bart., P.R.S.*"

Mr. Hamilton to the President of the Royal Society, in reply to his letter of 2nd June (not given here).

"Treasury Chambers, June 14, 1860.

"SIR,—In reply to your letter of the 2nd inst., with its enclosure from General Sabine relative to the establishment of Colonial Magnetic Observatories, I am directed by the Lords Commissioners of Her Majesty's Treasury to state that, without entering into the question what verbal assurances may have been given in December 1858 by the then Assistant Secretary, Sir Charles Trevelyan, of which no record was made, their Lordships observe that the main ground of their letter of the 16th May, 1860, remains unaffected, viz. that, in the opinion of the highest scientific authorities, whatever might be the value of observations at Vancouver Island, that value would be greatly increased by simultaneous observations at some station in the North of China, and, on the other hand, would be 'grievously diminished' if no station in China was established. Under these circumstances, their Lordships thought it desirable to postpone for a short time the consideration of the question, in the hope that it might be considered under a different state of things in China, rendering possible the attainment of the greatest amount of scientific advantage from the expenditure of public money, in case that expenditure should be decided upon.

"I am, Sir,
"Your obedient Servant,
(Signed) "G. A. HAMILTON."

General Sabine has written the following letter to Dr. Bache, who had intimated to him that, in the event of Her Majesty's Government declining to establish a magnetical observatory at Vancouver Island, it was the wish of the United States' Government to establish one in Washington Territory, in the vicinity of Vancouver Island:—

"May 22, 1860.

"DEAR BACHE,—I waited to reply to yours of April 13th until we should have received the reply of our Government regarding the Vancouver Island Observatory. Mr. Gladstone has availed himself of some expressions in Sir John Herschel's letters and mine (to the effect of the far greater importance of having observations on the Chinese as well as on the American side of the Pacific to having either separately) to postpone a decision regarding Vancouver Island until our relations with China shall enable our Government to consider the question of establishing both simultaneously. Our proposition, therefore, has fallen to the ground, and it is quite open to your Government to occupy the field which you were willing to concede to us in consideration of the forward part which our Government has hitherto taken in magnetic researches.

"Now in regard to the instruments, which, as you are probably aware, have been prepared at my own risk, in order that, should our Government accede to the recommendation made by the Royal Society and British Association, the time might be saved which must otherwise have been lost in their preparation. They have been made on the model of those which have been in use at the Kew Observatory since January 1858. An account of these is in the press, and will be published in the volume of Reports of the British Association for 1859–1860, which must be in circulation next month. I have thoroughly examined and computed the *declination* results for 1858 and 1859, by means of tabulated hourly values, and am now engaged in the same calculation of the Bifilar and Vertical Force Magnetometers. The Declination Report will be presented to the Royal Society, and printed in the 'Proceedings' in the course of the summer, as well as the results of the Force Magnetometers for the same two years, as soon as I am able to draw up the report in due form and order. But I am able to say, regarding all the three elements, that the instruments are *eminently* successful. Independent of the *continuity* of the record (which is of course a great thing in itself), the hourly tabulations are far more consistent and satisfactory than were the eye-observations at any of our observatories.

"In preparing a second set of instruments, therefore (which we have done for the proposed Netherlands Observatory in Java), we have had very few improvements to introduce, except the addition of reading-telescopes for each instrument—so that we may always retain the power of eye-observation, either in addition to or substitution for photographic records. Dr. Bergsma, the Director of the Java Observatory, is now at Kew, observing with his instruments, in comparison with those in our own Observatory (as we have a separate building for the instruments on trial), and will take them away towards the end of June. These of course will be paid for by the Netherlands Government, having been ordered expressly for them. There will then be the third set, which have been prepared for Vancouver, and which are ready to succeed the Java instruments in the experimental house. A few *very* trifling improvements have been introduced in these—none worthy of being noticed here. They at present stand as mine, and I shall be indebted £250 for them. The decision of Government, as communicated to the President of the Royal Society, makes no reference to my responsibility on their account. I am, therefore, to say the least, quite free to dispose of them as I may please. Now I am not rich enough to offer them as a *loan* to your 'Washington Territory' Observatory; but if you desire to have differential determinations there in addition to absolute determinations, I am persuaded that you could not have better instruments than these would be; and I consider myself as quite free to offer you the refusal of them, asking only in return that you will give me as early a reply as may be convenient, because I have some reason to expect that I may receive an application from the Sydney Observatory to obtain a duplicate of the Kew instruments; in which case, if you had not claimed them in the meantime, I should direct these to be sent to Sydney.

"Sincerely yours,

(Signed) "EDWARD SABINE."

"*Dr. Bache, F.R.S., Director of the*
Coast Survey of the United States."

The reply to this letter has not yet been received; but in the meantime the following application has come for a set of magnetical instruments for absolute determinations from Dr. Smallwood, Professor of Meteorology at M^cGill College in Montreal, Canada:—

"St. Martin, Isle Jésus, May 21, 1860.

"SIR,—I duly received yours of the 16th of July last, in reference to the establishment of a Magnetic Observatory here, in connexion with observations on meteorology and atmospheric electricity, and deferred writing until I was in a position to acquire the instruments necessary.

"You said in your communication that '£80 or thereabouts was required;' and you were kind enough to add, with a spirit of generosity I could not expect, 'that every care should be taken to superintend the construction of such instruments, to verify them, and to determine their constants, and have them carefully packed and sent out.'

"The object of the present letter is to ascertain, 1st, the exact cost (if possible); 2nd, to whom the amount shall be forwarded; 3rd, when the instruments would probably be ready; 4th, a short list of what are to be sent.

"I feel that I am asking too much from you; but a knowledge of your devotion to a science which you have so much extended, makes me feel less diffident, and I have thrown myself upon your kindness.

"I have also to acknowledge the receipt of a Book of Instructions, &c., with thanks.

"So soon as I get a reply from you, I will at once transmit the amount with the order, and submit a plan of the building.

"Believe me to remain, with great consideration and respect,
"Yours faithfully,
(Signed) "C. SMALLWOOD."

"*General Sabine, London.*"

Instruments to meet this request are in preparation.

The Committee have thought that it might not prove uninteresting to the members of the British Association, if, in this Report, a short description were given of the Kew Observatory, and of the nature and amount of work which is accomplished therein.

The Observatory is situated in the middle of the old Deer-park, Richmond, Surrey, and is about three-quarters of a mile from the Richmond Railway Station. Its longitude is 0° 18′ 47″ W., and its latitude is 51° 28′ 6″ N. It is built north and south. The repose produced by its complete isolation is eminently favourable to scientific research. In one of the lower rooms a set of self-recording magnetographs, described in the Report of the last meeting of this Association, is constantly at work. These instruments, by the aid of photography, furnish a continuous record of the changes which take place in the three magnetic elements, viz. the declination, the horizontal force, and the vertical force. The light used is that of gas, in order to obtain which, pipes have been carried across the Park to the Observatory, at an expense of £250, which sum was generously defrayed by a grant from the Royal Society.

Attached to this room is another, of a smaller size, in which the necessary photographic operations connected with magnetography are conducted.

In the story above the basement, the room by which the visitor enters the Observatory is filled with apparatus. Much of this is the property of the Royal Society, and some of the instruments possess a historical value; for instance, the air-pump used by Boyle; and the convertible pendulum designed by Captain Kater, and employed by him, and subsequently by General Sabine, in determining the length of the pendulum vibrating seconds.

An inner room, which opens from this one, is used as a library and sitting-room, and in it the calculations connected with the work of the Observatory are performed. In this room dipping-needles and magnets, which it is necessary to preserve from rust, are stored. Here also the MS. of the British Association Catalogue of Stars is preserved.

A room to the east of this contains the standard barometers, and the apparatus (described by Mr. Welsh in the 'Transactions' of the Royal Society, vol. 146. p. 507) for verifying and comparing marine barometers with the standard. This room has also accommodation for the marine barometers sent for verification. In the middle of the room is a solid block of masonry, extending through the floor to the ground below. To this an astronomical quadrant was formerly attached; it is now used as a support for the standard barometers. This room contains also a Photographic Barograph invented by Mr. Francis Ronalds, which, though not at present in operation, may serve as a model for any one who wishes to have an instrument of this description. It is described by Mr. Ronalds in the Report of the British Association for 1851.

In a room to the west of the Library, thermometers for the Board of Trade, the Admiralty, and opticians, are compared with a standard thermometer by means of a very simple apparatus devised by the late Mr. Welsh.

The Observatory also possesses a dividing-engine by Perreaux, by means of which standard thermometers are graduated. It was purchased by a grant from the Royal Society.

In this room the pure water required for photographic processes is obtained by distillation; and here also a small transit telescope is placed for ascertaining time. The transit instrument is erected in a line between two meridian marks—one to the north and the other to the south of the Observatory; so that, by means of suitable openings, either of these marks may be viewed by the telescope.

In a higher story is the workshop, containing, among other things, a slide-lathe by Whitworth, and a planing machine by Armstead, both of which were presented to the Kew Observatory by the Royal Society.

In the dome is placed the Photoheliograph for obtaining pictures of the sun's disk; attached to the dome there is a small chamber in which the photographic processes connected with the photoheliograph are conducted. This chamber is supplied with water by means of a force-pump. A self-recording Robinson's anemometer is also attached to the dome.

In addition to the rooms now specified, there are the private apartments attached to the Observatory.

On the north side of the Observatory there is an apparatus similar to that used at the Toronto Observatory for containing the wet- and dry-bulb, the maximum and the minimum thermometers.

The model magnetic house, elsewhere alluded to in this Report, stands at a distance of about 60 yards from the Observatory; and the small wooden house in which the absolute magnetic observations are made, at a distance of about 110 yards. These houses are within a wooden paling, which fences them off from the remainder of the Park, and encloses about one acre of ground attached to the Observatory.

The work done may now be briefly specified. In the first place, the self-recording magnetographs, as already mentioned, are kept in constant operation, and record the changes continually occurring in the magnetic elements.

The photographs are sent to General Sabine's establishment at Woolwich, to undergo the processes of measurement and tabulation.

In the model magnetic house there is at present a set of magnetographs which Dr. Bergsma will take to Java. When this set is removed another will supply its place, in readiness for any other Observatory, colonial or foreign, at which it may be required.

In the house for absolute determinations, monthly values of the declination, dip, and horizontal magnetic force are taken, and magnetic instruments for foreign or colonial observatories have their constants determined.

Accounts of the Kew Committee of the British Association from September 14, 1859 *to June* 27, 1860.

RECEIPTS.	£	s.	d.	£	s.	d.
Balance from last account				8	9	8
Received from the General Treasurer				500	0	0
„ for the verification of Instruments—						
from the Board of Trade	20	14	0			
from the Admiralty	62	19	0			
from Opticians	32	16	8			
				116	9	8
„ for standard Thermometers				3	8	0
„ from the Royal Society to defray the expense of erecting a wooden house in which to receive and examine Magnetographs for Foreign or Colonial Observatories				179	12	6
„ from the Royal Society in part payment of the Kew Magnetographs				150	0	0
				£957	19	10

PAYMENTS.	£	s.	d.	£	s.	d.
Salaries, &c.:—						
To B. Stewart, three quarters, ending June 30, 1860	150	0	0			
Ditto, allowed for petty travelling expenses	10	0	0			
C. Chambers, three quarters, ending July 6, 1860	75	0	0			
J. V. Magrath, six months, ending Feb. 14, 1860	35	0	0			
R. Beckley, 41 weeks, ending June 25, 1860, at 35*s.*	71	15	0			
G. Whipple, 40 weeks, ending June 18, 1860, at 12*s.*	24	0	0			
T. Baker, 15 weeks, ending June 25, 1860, at 8*s.*	6	0	0			
				371	15	0
Apparatus, Materials, Tools, &c.				64	6	1
Ironmonger, Carpenter, and Mason				32	19	9
Printing, Stationery, Books, and Postage				22	3	6
Coals and Gas				39	16	6
House Expenses, Chandlery, &c.				17	6	7
Porterage and petty expenses				11	5	4
Rent of Land	10	10	0			
Ditto, undercharged in last account	10	10	0			
				21		0
Cost of building a Wooden House in which to receive and examine Magnetographs for Foreign or Colonial Observatories				179	12	6
Optician's account for the Kew Magnetographs				186	6	2
Balance in hand				11	8	5
				£957	19	10

I have examined the above account and compared it with the vouchers presented to me, and find that the Balance in hand is Eleven pounds Eight shillings and Fivepence.

18*th June*, 1860.

R. HUTTON.

In the meteorological department, all the barometers, thermometers, and hydrometers required by the Board of Trade and the Admiralty have their corrections determined; besides which, similar instruments are verified for opticians. Standard thermometers also are graduated, and daily meteorological observations are made, an abstract of which is published in the 'Illustrated London News.'

Instruction is also given in the use of instruments to officers in the army or navy, or other scientific men who obtain permission from the Committee.

All this amount of work, it is believed, can be executed by the present staff, consisting of the superintendent, three assistants (magnetical, mechanical, and meteorological), and a boy; but the expense attending it is greater than the present income of the Observatory, furnished by the British Association, will support.

In the resolution of the British Association of the 14th September, 1859, it was recommended to Government, at the instance of the joint committee of the Royal Society and British Association, that the sum of £350 per annum should be placed at the disposal of the general superintendent of the magnetical observations; this sum was intended to have defrayed the expenses attending the magnetical department of the Observatory and the observations of the sun's spots. It will be seen, however, from the correspondence contained in an earlier part of this Report, that this source of income is not yet available.

JOHN P. GASSIOT,
Chairman.

June 18, 1860.

Report of the Parliamentary Committee to the Meeting of the British Association at Oxford in June 1860.

The Parliamentary Committee have the honour to report as follows:—

No subject of sufficient importance to require any especial notice has occupied their attention during the past year, nor indeed was there any matter referred to them at the last Meeting of the Association.

There are now either two or three vacancies in that portion of the Committee which represents the House of Commons, according as it shall be determined whether the vacancy caused in that Section by Lord de Grey's taking his seat in the House of Lords is or is not to be filled up,

WROTTESLEY, *Chairman.*

May 28, 1860.

RECOMMENDATIONS ADOPTED BY THE GENERAL COMMITTEE AT THE OXFORD MEETING IN JUNE AND JULY 1860.

[When Committees are appointed, the Member first named is regarded as the Secretary of the Committee, except there be a specific nomination.]

Involving Grants of Money.

That the sum of £500 be appropriated to the maintenance of the Establishment in Kew Observatory, under the direction of the Council.

That a sum not exceeding £90 be granted for one year for the payment of an additional Photographer for carrying on the Photo-heliographic Observations at Kew.

That a sum not exceeding £30 be placed at the disposal of Mr. Broun, Dr. Lloyd, and Mr. Stone, for the construction of an Induction Dip Circle, in connexion with the Observatory at Kew.

That a sum not exceeding £10 be placed at the disposal of Professor Tyndall and Mr. Ball, for providing Instruments for making Observations in the Alps, and for printing the formulæ for the use of travellers.

That the Balloon Ascent Committee, consisting of Prof. Walker, Prof. W. Thomson, Sir D. Brewster, Dr. Sharpey, Dr. Lloyd, Col. Sykes, General Sabine, and Prof. J. Forbes, be reappointed, with the addition of Mr. Broun; and that the sum of £200 be placed at their disposal for the purpose.

That Dr. Matthiessen be requested to prosecute his Experiments on the Chemical Nature of Alloys; and that the sum of £20 be placed at his disposal for the purpose.

That Prof. Sullivan be requested to continue his Experiments on the Solubility of Salts at Temperatures above 100° Cent., and on the mutual Action of Salts in Solution; and that the sum of £20 be placed at his disposal for the purpose.

That Prof. Voelcker be requested to continue his investigation on Field Experiments and Laboratory Researches on the Constituents of Manures essential to Cultivated Crops; and that the sum of £25 be placed at his disposal for the purpose.

That Mr. Alphonse Gages be requested to continue his Experiments on the Mechanico-Chemical Analysis of Minerals; and that the sum of £20 be placed at his disposal for the purpose.

That Mr. Mallet be requested to carry on his Experiments on Earthquake Waves; and that the sum of £25 be placed at his disposal for the purpose.

That additional excavations be made at Dura Den by the Committee, now consisting of Dr. Anderson, Prof. Ramsay, Prof. Nicol, and Mr. Page; that Mr. J. B. Jukes be added to the Committee; and that the sum of £20 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Dr. Lukis, Mr. Spence Bate, Mr. A. Hancock, and Dr. Verloren be a Committee for the purpose of Reporting on the best mode of preventing the ravages of the different kinds of Teredo and other Animals in our Ships and Harbours; that Mr. J. Gwyn Jeffreys be the Secretary; and that the sum of £10 be placed at their disposal for the purpose.

That Mr. Sclater, Dr. A. Günther, and Mr. R. T. Tomes be a Committee for the purpose of preparing and printing a Report on the Present State of our Knowledge of the Terrestrial Vertebrata of the West India Islands; that Mr. Sclater be the Secretary; and that the sum of £10 be placed at their disposal for the purpose.

That Mr. Robert MacAndrew and the following gentlemen be a Committee for General Dredging purposes:—Mr. R. MacAndrew, Chairman; Mr. G. C. Hyndman, Dr. Edwards, Dr. Dickie, Mr. C. L. Stewart, Dr. Collingwood, Dr. Kinahan, Mr. J. S. Worthey, Mr. J. Gwyn Jeffreys, Dr. E. Perceval Wright, Mr. Lucas Barrett, and Professor J. R. Greene. That Mr. Robert MacAndrew be the Secretary; and that the sum of £25 be placed at their disposal for the purpose.

That Dr. Ogilvie, Dr. Dickie, Dr. Dyce, Prof. Nicol, and Mr. C. W. Peach be a Committee for the purpose of Dredging the North and East Coasts of Scotland. That Dr. Ogilvie be the Secretary; and that the sum of £25 be placed at their disposal for the purpose.

That the surviving members of the Committee appointed in the year 1842, viz. Mr. C. Darwin, Rev. Professor Henslow, Rev. L. Jenyns, Mr. W. Ogilby, Professor Phillips, Sir John Richardson, Mr. J. O. Westwood, Professor Owen, Mr. W. E. Shuckard, and Mr. G. R. Waterhouse, for the purpose of preparing Rules for the establishment of a Uniform Zoological Nomenclature, be reappointed, with the addition of Sir William Jardine, Bart., and Mr. P. L. Sclater. That Sir W. Jardine be the Secretary; and that the sum of £10 be placed at their disposal for the purpose of revising and reprinting the Rules.

That Mr. Sclater and Dr. F. Hochstetter be a Committee for the purpose of drawing up a Report on the Present State of our Knowledge of the Species of *Apteryx* living in New Zealand. That Mr. Sclater be the Secretary; and that the sum of £50 be placed at their disposal for the purpose.

That Dr. Collingwood be requested to dredge in the Estuaries of the Mersey and Dee; and that the sum of £5 be placed at his disposal for the purpose.

That Dr. Edward Smith, F.R.S., and Mr. Milner be a Committee for the purpose of prosecuting inquiries as to the effect of Prison Diet and Discipline upon the Bodily Functions of Prisoners. That Dr. Edward Smith be the Secretary; and that the sum of £20 be placed at their disposal for the purpose.

That Mr. T. Wright, Mr. J. B. Davis, and Mr. A. G. Hindlay be a Committee for the purpose of exploring entirely the piece of ground at Uriconium in which the human remains have been found, in order to examine more fully the circumstances connected with the discovery, and to obtain the similar Skulls which may still remain under ground. That Mr. T. Wright be the Secretary; and that the sum of £20 be placed at their disposal for the purpose.

That Professor James Thomson (of Belfast) be requested to continue his Experiments on the Gauging of Water; and that the sum of £10 be placed at his disposal for the purpose.

That the Committee on Steam-ship Performance be reappointed, to report proceedings to the next Meeting; that the attention of the Committee be also directed to the obtaining of information respecting the performance of vessels under Sail, with a view to comparing the results of the two powers of Wind and Steam, in order to their most effective and economical combination; and that the sum of £150 be placed at their disposal for this purpose. The following gentlemen were nominated to serve on the Committee:—Vice-Admiral Moorsom; The Marquis of Stafford, M.P.; The Earl of Caithness; The Lord Dufferin; Mr. William Fairbairn, F.R.S.; Mr. J. Scott Russell, F.R.S.; Admiral Paris, C.B.; The Hon. Captain Egerton, R.N.; Mr. William Smith, C.E.; Mr. J. E. M^{c}Connell, C.E.; Prof. Rankine, LL.D.; Mr. J. R. Napier, C.E.; Mr. R. Roberts, C.E.; Mr. Henry Wright, Honorary Secretary; with power to add to their number.

That Prof. Phillips be requested to complete and print, before the Manchester Meeting, a Classified Index to the Transactions of the Association from 1831 to 1860 inclusive; that he be authorized to employ, during this period, an Assistant; and that the sum of £100 be placed at his disposal for the purpose.

Applications for Reports and Researches.

That Mr. H. J. S. Smith be requested to continue his Report on the Theory of Numbers.

That Mr. Cayley be requested to draw up a Report on certain Problems in Higher Dynamics.

That Mr. B. Stewart be requested to draw up a Report on Prevost's Theory of Exchanges, and its recent extensions.

That Prof. Stokes be requested to draw up a Report on the Present State and Recent Progress of Physical Optics.

That Dr. Dickie be requested to draw up a Report on the Flora of Ulster, for the next Meeting of the Association.

That Dr. Carpenter be requested to draw up a Report on the Minute Structure of Shells.

That Dr. Michael Foster be requested to report upon the Present State of our Knowledge in reference to Muscular Irritability.

That Mr. James Oldham be requested to continue his Report on Steam Navigation in the Port of Hull.

That the Lord Rosse, Dr. Robinson, Professor Phillips, and Mr. W. R. Birt be a Committee for the purpose of making observations on the Moon's surface and comparing it with that of the Earth. That Professor Phillips be the Secretary.

That the Rev. Professor Price, Dr. Whewell, Sir J. Lubbock, Admiral FitzRoy, Sir W. S. Harris, and Rev. Professor Haughton be a Committee for the purpose of reporting to the next Meeting of the British Association, on the Expediency and best means of making Tidal Observations, with a view to the completion of Dr. Whewell's Essays in prosecution of a full Tidal Exposition.

That, as it would be highly desirable that the observations on the Magnetic Lines in India should be continued, His Highness The Rajah of Travancore be requested to complete the Survey already commenced by him, through his Astronomer.

That it is desirable that a Committee be appointed to consider the best mode of effecting the registration and publication of the numerical facts of Chemistry. That the Committee consist of Dr. Frankland, Dr. W. A. Miller, Prof. W. H. Miller, Prof. Brodie, Prof. Williamson, and Dr. Lyon Playfair.

That the Lords of the Admiralty be moved to authorize some small vessel stationed on the South-East Coast of America to take a convenient opportunity of collecting specimens of the large Vertebrate Fossils from certain localities easy of access between the River Plata and the Straits of Magellan.

That Sir W. Jardine, Bart., Prof. Owen, Prof. Faraday, and Mr. Andrew Murray be a Committee for the purpose of procuring information as to the best means of conveying Electrical Fishes alive to Europe. That Sir W. Jardine be the Secretary.

That Mr. William Fairbairn, Mr. J. F. Bateman, and Prof. Thomson be a Committee for the purpose of reporting on Experiments to be made at the Manchester Waterworks on the Gauging of Water; with power to add to their number.

That the Committee to report on the Rise and Progress of Steam Navigation in the Port of London be reappointed, and that the following gentlemen be requested to serve on it:—Mr. William Smith, C.E.; Sir John Rennie, F.R.S.; Captain Sir Edward Belcher; Mr. George Rennie, F.R.S.; Mr. Henry Wright, Secretary; with power to add to their number.

Involving Applications to Government or Public Institutions.

That the Parliamentary Committee, now consisting of the Duke of Argyll, Duke of Devonshire, Earl de Grey, Lord Enniskillen, Lord Harrowby, Lord Rosse, Lord Stanley, Lord Wrottesley, Bishop of Oxford, Sir Philip Egerton, Sir John Packington, be requested to recommend two members of the House of Commons to fill the two vacancies.

That Sir Roderick I. Murchison, as Trustee of the Association, and Mr. Nassau W. Senior, as President of the Section of Economic Science and Statistics, be a Delegacy for the purpose of attending the International Statistical Congress in London on July 16.

That the Committee on Steam-ship Performance be requested to communicate with the Parliamentary Committee, for the purpose of obtaining their assistance in accomplishing the objects for which the Committee on Steamships was appointed.

Communications to be printed entire among the Reports.

That the Communications by the Rev. W. V. Harcourt, on the results of Experiments at the Low Moor Iron Works, be printed entire among the Reports of the Association.

That Mr. William Fairbairn's Paper, on Experiments to determine the effect of vibratory action and long-continued changes of load upon Wrought-iron Girders, be printed entire in the Reports of the Association.

That Admiral Moorsom's Paper, on the Performance of Steam Vessels, be printed entire among the Reports.

That Mr. Elder's Paper, on a cylindrical spiral boiler, with comparative evaporating power and temperatures of furnaces, flues and chimneys of various boilers, be printed entire in the Transactions of the Sections, with the necessary diagrams.

Synopsis of Grants of Money appropriated to Scientific Objects by the General Committee at the Oxford Meeting in June and July 1860, with the name of the Member, who alone, or as the First of a Committee, is entitled to draw for the Money.

	£	s.	d.
Kew Observatory.			
Kew Observatory Establishment	500	0	0
Mathematical and Physical Science.			
Photo-heliographic Observations at Kew	90	0	0
TYNDALL and BALL.—Alpine Ascents	10	0	0
Carried forward	600	0	0

	£	s.	d.
Brought forward	600	0	0
Balloon Committee	200	0	0
Broun and Committee.—Dip-circle	30	0	0
Chemical Science, including Mineralogy.			
Matthiessen, Dr.—Chemical Alloys	20	0	0
Sullivan, Professor.—Solubility of Salts	20	0	0
Voelcker, Professor.—Constituents of Manures	25	0	0
Gages, Alphonse.—Chemistry of Rocks and Minerals	20	0	0
Geology.			
Mallet, Robert.—Earthquake Observations	25	0	0
Committee.—Excavations at Dura Den	20	0	0
Zoology and Botany.			
Jeffreys, J. G., and Committee.—Ravages of Teredo and other Animals	10	0	0
Sclater, P. L., and Committee.—Report on Terrestrial Vertebrata of West Indies	10	0	0
MacAndrew, R., and Committee.—For General Dredging	25	0	0
Ogilvie, Dr., and Committee.—Dredging the North and East Coasts of Scotland	25	0	0
Jardine, Sir W., Bart., and Committee.—Revising and Reprinting Rules of Zoological Nomenclature	10	0	0
Sclater, P. L.—Investigation of Apteryx	50	0	0
Collingwood, Dr.—Dredging in Mersey and Dee	5	0	0
Physiology.			
Dr. Edward Smith, F.R.S., and Mr. Milner.—Effect of Prison Diet and Discipline upon the bodily functions of Prisoners	20	0	0
Geography and Ethnology.			
Committee for exploring Uriconium	20	0	0
Mechanical Science.			
Thomson, Professor J.—Gauging of Water	10	0	0
Committee on Steam-Ship Performance	150	0	0
Classified Index to the Transactions.			
Professor Phillips (to employ an Assistant)	100	0	0
Total....	£1395	0	0

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	89	5	3
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0

	£	s.	d.
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	6
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3

	£	s.	d.
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology 1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument, 1842	10	3	6
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£830	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1839	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	3
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1839	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0

	£	s.	d.
Periodical Phenomena	15	0	0
Meteorological Instrument, Azores	25	0	0
	£345	18	0
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phænomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855.			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

	£	s	d.
1856.			
Maintaining the Establishment at Kew Observatory:— 1854......£ 75 0 0 1855......£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4
1858.			
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2
1859.			
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam Vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	0
Balloon Ascents	39	11	1
	£684	11	1

1860.	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£1241	7	0

Extracts from Resolutions of the General Committee.

Committees and individuals, to whom grants of money for scientific purposes have been entrusted, are required to present to each following meeting of the Association a Report of the progress which has been made; with a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of pecuniary aid for scientific purposes from the funds of the Association expire at the ensuing meeting, unless it shall appear by a Report that the Recommendations have been acted on, or a continuation of them be ordered by the General Committee.

In each Committee, the Member first named is the person entitled to call on the Treasurer, John Taylor, Esq., 6 Queen Street Place, Upper Thames Street, London, for such portion of the sum granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named shall be deemed to include, as a part of the amount, the specified balance which may remain unpaid on the former grant for the same object.

General Meetings.

On Wednesday, June 27, at 4 P.M., in the Sheldonian Theatre, His Royal Highness, the Prince Consort, resigned the office of President to The Lord Wrottesley, F.R.S., who took the Chair and delivered an Address, for which see page lv.

On Thursday Evening, June 28, at 8½ P.M., a Conversazione took place in the University Museum.

On Friday Afternoon, June 29, at 4 P.M., in the Sheldonian Theatre, the Rev. Professor Walker, F.R.S., delivered a Discourse on the Physical Constitution of the Sun.

On Friday Evening, the University Museum was opened for a Soirée with Experiments.

On Monday Afternoon, July 2, at 2 P.M., in the Sheldonian Theatre, Captain Sherard Osborn, R.N., delivered a Discourse on Arctic Discovery.

On Monday Evening, at 8½ P.M., a Conversazione took place in the University Museum.

On Tuesday Evening, July 3, at 8½ P.M., the University Museum was opened for a Soirée with Microscopes.

On Wednesday, July 4, at 3 P.M., the concluding General Meeting took place in the Sheldonian Theatre, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The Meeting was then adjourned to Manchester*.

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* The Meeting is appointed to take place on Wednesday, the 4th of September, 1861.

ADDRESS

BY

THE RIGHT HON. THE LORD WROTTESLEY.

GENTLEMEN,—If, on taking this Chair for the first time as your President, I do not enlarge upon my deficiencies for adequately filling the responsible office to which you have done me the honour to elect me, I hope you will believe that I am not the less sensible of them.

Your last Meeting was held under the Presidency of one not more distinguished by his high rank and exalted station than by his many excellent qualities, and the discriminating interest which he has ever manifested in the promotion of Art and Science. It was one of the most successful Meetings on record.

We are now once more assembled in this ancient and venerable seat of learning; and the first topic of interest which presents itself to me, who owe to Oxford what academic training I have received, is the contrast presented by the state of Science and the teaching of Science in this University in the Autumn of the year 1814, when my residence here commenced, and for five years afterwards, with its present condition. As the private pupil of the late Dr. Kidd, and within a few yards of the spot from which I have now the honour to inaugurate the Meeting of this distinguished Association, I first imbibed that love of Science from which some of the purest pleasures of my life have been derived; and I cannot mention the name of my former Tutor without acknowledging the deep debt of gratitude I owe to the memory of that able, conscientious and single-hearted man.

It was at this period that a small knot of Geologists, headed by Broderip, Buckland, the two Conybeares and Kidd, had begun to stimulate the curiosity of the Students and resident Graduates by Lectures and Geological excursions in the neighbourhood of this town. The lively illustrations of Buckland, combined with genuine talent, by degrees attracted crowds to his teaching, and the foundations of that interesting science, already advancing under the illustrious Cuvier in France, and destined soon to spread over Europe, were at this time fairly laid in England within these classical Halls. Many a time in those days have my studies been agreeably interrupted by the cheerful laugh which invariably accompanied the quaint and witty terms in which Buckland usually announced to his brother Geologist some new discovery, or illustrated the facts and principles of his favourite science. At the time, however, to which I refer, the study of physical science was chiefly confined to a somewhat scanty attendance on the Chemical Lectures of Dr. Kidd, and on those on Experimental Philosophy by Rigaud; and in pure mathematics the fluxional notation still kept its ground. In the year 1818 Vince's Astronomy, and in the following year the Differential Notation, was first introduced in the mathematical examinations for honours. At that time that fine foundation the Radcliffe Observatory was wholly inactive; the observer was in declining health, and the establishment was neither useful to astronomical students, nor did it contribute in any way to the advancement of Astronomical Science. Even from the commencement of the present century, and in proportion as the standard of acquirement in classical learning was gradually raised by the emulation excited by the examinations for honours, the attendance on the above-mentioned Lectures gradually declined: but a similar cause enhanced the acquirements of students in pure and applied Mathematics, and the University began to number among its Graduates and Professors men of great eminence in those departments of knowledge. Nor were the other sciences neglected; and as Chairs became vacant or new Professorships were established, men of European reputation were appointed to fill them. In proof of all this I need only direct attention to the names on the roll of Secretaries, Vice-Presidents and Presidents of Sections, to convince you that Oxford now contains among her resident Graduates, men amply qualified to establish and advance the scientific fame of that University, of which they are the distinguished ornaments.

On the progress of Astronomy I will, as becomes me, enter into more detail. And it is not without pain that I allude to this subject, because I am reminded that one has been removed from among us by the hand of death, whom I had looked forward to meeting again on this occasion with peculiar pleasure. I never knew any one who had the interests of science more truly at heart, or laboured more diligently to advance them, than the late Radcliffe Observer, Mr. Manuel Johnson. By his exertions and indefatigable zeal the Radcliffe Observatory was enabled to take its proper place among the Scientific Institutions of the world. By the liberality of the Trustees and by the exertion of his influence, new instruments were purchased, and an extensive series of valuable astronomical observations was made; and, what is quite as important, they were regularly reduced and published. In addition to all this, a noble array of self-recording meteorological instruments was brought into action, and their records duly reduced and co-ordinated. I was myself a candidate in 1839 for that office to which Mr. Johnson was then appointed, and I have often rejoiced that I was not successful, as it would have retarded for a time the promotion of one, to whom Astronomy owes a deep debt of gratitude. Mr. Johnson was suddenly taken from us at a time when he was in the full career of his useful labours, and there are few labourers in science whose loss has been more deplored. The University has very lately lost another learned Professor, and myself another valued friend, whose contributions to science are well known and duly esteemed. The great tragic Poet of Greece introduces his hero accusing his heathen gods of rescuing from the grave the vile and worthless, and sending thither the good and useful:—

> ...... τὰ δὲ δίκαια καὶ τὰ χρηστὰ
> ἀποστέλλουσιν ἀεί.

Our purer faith in meek resignation trusts that they are removed from evil to come, and that there at least they rest from their labours—rest from earthly toil and trouble, but awake, may be, to higher aims and aspirations, and with nobler faculties and duties.

Although a successor may be appointed to Mr. Johnson, who will, I doubt not, admirably discharge the duties of Radcliffe Observer, I fear that the Observatory may not continue to maintain its high reputation, unless a sufficient staff of Assistants be appointed to aid the Observer in his labours. There is no mistake more fatal in Astronomy than that of multiplying instrumental means without providing an adequate supply of hands to employ them.

I have already alluded to some particulars in which this great University has advanced in the career of scientific improvement, but everything else has been somewhat thrown into the shade by the important event of this year, the opening of the new Museum. The University could have given no more substantial proof of a sincere interest in the diffusion of science than the foundation of this noble Institution, and I am sure that among the distinguished cultivators of science here assembled, there is not one who does not entertain a hearty desire for the success of the various efforts now in progress for the purpose of stimulating our University Students to a closer contemplation and more diligent study of the glorious works of Nature; a study, which, if prosecuted earnestly, raises us in the scale of human beings and improves every moral and intellectual faculty. Towards the attainment of a result so much to be desired the Museum will most powerfully contribute, and those who frequent it will owe deep obligations to Mr. Hope and the other benefactors who have generously added to its stores. But there are other causes in operation which tend to the same end; and among them, in addition to such improvements as arise out of the changes consequent on the recent Act of Parliament, may be mentioned the alteration in the distribution of University Honours.

The institution of the School of Physical Science forms a most important feature in the recent changes, and will doubtless be productive of good results, provided that sufficient encouragement by way of reward be held out to those whose tastes lead them to devote themselves to those departments of knowledge, and that the compulsory arrangements in respct of other studies allow sufficient time to the student to accomplish his object. The great majority of physical students must necessarily belong to that class who have their subsistence to earn; and however earnest may be their zeal for mental improvement, there will be few candidates for the honours of the Physical School unless due encouragement be given to excellence in that department. It was therefore with sincere pleasure that I learnt that three Fellowships had been founded at Magdalen College as prizes for proficiency in Natural Science; and that at the same College, and at Christ Church and Queen's, Scholarships and Exhibitions had been provided for students who evince during their examinations the greatest aptitude for such studies. Moreover, the acquisition of a Radcliffe travelling Fellowship has been made to depend upon obtaining distinction in the School of Natural Science. In addition to all this, that beneficent and enlightened lady, Miss Burdett Coutts, has founded two Scholarships with the view of extending among the Clergy educated at the University a knowledge of Geology. Great hopes are justly excited in the minds of all well-wishers to the University by these events, and by reflection on the great change of opinion which must have taken place since the period when Dr. Kidd, with the aid of Dr. Daubeny, Mr. Greswell and others, in vain attempted to raise a small sum by private subscription for building a modest receptacle for the various collections of Natural History. How little could these public-spirited individuals have foreseen, that within a few short years a sum approaching to £100,000 would be appropriated to the building and furnishing that splendid monument of Oxford's good will to science, the New Museum!

It would not be right, however, if, while speaking in just and sincere terms of praise of all that excites my admiration in the late proceedings at Oxford, I were to withhold the honest expression of my opinion on points on which I feel compelled to differ from the course pursued. I will therefore refer to two measures, one of which especially I cannot but regard as a mistake. The first is the repeal of the statute which enforced attendance on two courses of Professorial lectures; a requirement, which may have had no small influence in creating a taste for natural science among that large class of students, whose only object it is to obtain, in a creditable manner if possible, but at all events to obtain, the distinction of an Academical degree. At the same time I cannot but be sensible that the amount of instruction imparted in this way, even if the attendance were much more than nominal, must necessarily have been small, not from any want of competency in the teachers, but from the inherent defect of the system of lectures unaccompanied by examinations; and on this account I the less regret the change.

The second, and more serious mistake, in my humble opinion, is the rejection by the Congregation in 1857 of the proposal of the Hebdomadal Council, that the Undergraduate, after passing his first two classical examinations, should be permitted to select his own line of study, and submit himself at his option to a final examination in any one of the four Schools, that is, the Classical, the Mathematical, History and Law, or Natural Science. The Hebdomadal Council were I think right in believing that such mental discipline as classical study can impart—and far be it from me to undervalue it in the least—would be sufficiently secured by the classical requirements of the two first examinations; and that the study of Mathematics and the Natural Sciences, besides imparting much valuable information, which might be extensively utilized in after-life, might equally be viewed as an important means of improving the intellectual faculties. There is another consideration which must not be lost sight of in deciding on the policy of the course then pursued. I think that it cannot in fairness be expected that a young man of the average abilities of those who contend for honours, and who is called upon to pass two classical examinations, and prepare for a third, before he is allowed to follow the bent of his genius and apply himself to his favourite study, can find time to attain a sufficient proficiency in it to pass a really creditable examination; accordingly the necessary result will be that the Examiners will be obliged to lower the standard of honour, the rather that most of the students now come to the University without having acquired even the elements of scientific knowledge, and thus the first class may almost cease to be a distinction worth attainment.

I cannot take leave of recent University changes without adverting to that great, that noble step, the institution of the Middle Class Examinations, whereby Oxford has furnished substantial aid to those more humble aspirants to knowledge, by whom a University education, however much desired, is quite unattainable. Whether this movement be viewed in its moral effect, as showing a kindly sympathy of the higher intellectual class with the struggling but deserving children of a lower sphere, or as the best expedient for bringing about a complete reform in our educational establishments, and therefore a great engine for advancing popular education—whether this grand and liberal step be viewed in one or both these aspects, it has given the most unmixed and heartfelt satisfaction to all who have the moral and mental improvement of the nation sincerely at heart; and greatly do I rejoice that such a satisfactory proof should have been given of a desire to make University Institutions a general national blessing.

Oxford, then, has shown herself fully equal to her glorious mission, and it was only a fitting sequel to such enlightened conduct, that she should be entrusted with the grateful task of educating the Heir apparent to the Throne of the most popular Sovereign who ever swayed the sceptre of this vast Empire.

I shall perhaps be forgiven if my former connexion with Oxford, and the interest which I must ever take in everything appertaining to my own University, have induced me to dwell somewhat at length on the above matters. It is now time that I should direct my attention to the general domain of science; but more particularly to that department to which my own labours, humble though they be, have been more especially devoted,—I mean the science of Astronomy, a science, which, whether we consider the surpassing interest of the subjects with which it is conversant, or the lofty nature of the speculations to which its inquiries lead, must ever occupy a most distinguished, if not the first place among all others.

In a discourse addressed in May 1859 to the Imperial Academy of Sciences of Vienna, by the distinguished Astronomer Littrow, a very full account is given of the voluntary contributions of the private observers of all nations to the extension of the science of Astronomy; and this discourse concludes with a remarkable sentence, of which our English Amateurs may well be proud: he expresses a hope that on the next occasion in which he shall be called upon to dilate on the same theme, he shall not as then have to mention English names in such preponderating numbers.

At the beginning of the year 1820, when the Astronomical Society was founded, the private Observatories in this country were very few in number. The establishment of that Society gave a most remarkable stimulus to the cultivation of the science which it was intended to promote. I can give no better proof of this than the fact that the Nautical Almanac now contains a list of no less than twelve private Observatories in the United Kingdom, at nearly all of which some good work has been done; and in addition to this, some Observatories, which have been since discontinued, have performed most important services—I may instance that of the two Herschels at Slough, and that of Admiral Smyth at Bedford.

It may not be uninteresting if I describe the nature and utility of some of the results which these several establishments have furnished to the world: I say the *world* advisedly, for scientific facts are the common inheritance of all mankind.

But first a word as to the peculiar province of the observatories which are properly called "public," such as the far-famed Institution at Greenwich. Their task is now more peculiarly to establish with the last degree of accuracy the places of the principal heavenly bodies of our own system, and of the brighter or fundamental fixed stars, which are about 100 in number. But in the early stages of Astronomy, we were necessarily indebted to public Observatories for all the data of the science. On the other hand, their voluntary rivals occupy that portion of the great astronomical field which is untilled by the professional observer; roving over it according to their own free will and pleasure, and cultivating with industrious hand such plants as the more continuous and severe labours of the public Astronomer leave no time or opportunity to bring to maturity.

The observations of our private observers have been chiefly devoted to seven important objects:—

First. The observing and mapping of the smaller stars, under which term I include all those which do not form the peculiar province of the public observer.

Secondly. The observations of the positions and distances of double stars.

Thirdly. Observations, delineations, and Catalogues of the Nebulæ.

Fourthly. Observations of the minor planets.

Fifthly. Cometary observations.

Sixthly. Observations of the solar spots, and other phenomena on the Sun's disc.

Seventhly. Occultations of stars by the Moon, eclipses of the heavenly bodies, and other occasional extra-meridional observations.

And first as to cataloguing and mapping the smaller stars. This means, as you know, the accurate determination by astronomical observation of the places of those objects, as referred to certain assumed fixed points in the heavens. The first Star Catalogue worthy to be so called, is that which goes by the name of Flamsteed's, or the British Catalogue. It contains above 3000 stars, and is the produce of the labours of the first Astronomer Royal of Greenwich, labours prosecuted under circumstances of great difficulty, and the results of which were not given to the world in a complete form till many years had elapsed from the time the observations were made, which was during the latter half of the seventeenth century. About the middle of the eighteenth century, the celebrated Dr. Bradley, who also filled the post of Astronomer Royal, observed an almost equally extensive Catalogue of Stars, and the beginning of the nineteenth century gave birth to that of Piazzi of Palermo. These three are the most celebrated of what may be now termed the ancient Catalogues. About the year 1830 the attention of modern astronomers was more particularly directed to the expediency of re-observing the stars in these three Catalogues, a task which was much facilitated by the publication of a very valuable work of the Astronomical Society, which rendered the calculations of the observations to be made comparatively easy, and accordingly observations were commenced and completed in several public and private Observatories, from which some curious results were deduced, as *e. g.*, sundry stars were found to be missing, and others to have what is called *proper motion*. And now a word as to the utility of this course of observation. It is well observed by Sir John Herschel, "that the stars are the landmarks of the Universe; every well-determined star is a point of departure which can never deceive the astronomer, geographer, navigator, or surveyor." We must have these fixed points in order to refer to them all the observations of the wandering heavenly bodies, the planets and the comets. By these fixed marks we determine the situation of places on the earth's surface, and of ships on the ocean. When the places of the stars have been registered, celestial charts are constructed; and by comparing these with the heavens, we at once discover whether any new body be present in the particular locality under observation: and thus have most of the fifty-seven small or minor planets between Mars and Jupiter been discovered. The observations, however, of these smaller stars, and the registry of their places in Catalogues, and the comparisons of the results obtained at different and distant periods, have revealed another extraordinary fact, no less than that our own Sun is not fixed in space, but that it is constantly moving forward towards a point in the constellation Hercules, at the rate, as it is supposed, of about 18,000 miles an hour, carrying with it the whole planetary and cometary system; and if our Sun moves, probably all the other stars or suns move also, and the whole universe is in a perpetual state of motion through space.

The second subject to which the attention of private observers has been more particularly directed, is that of double or multiple stars, or those which, being situated very close to one another, appear single to the naked eye, but when viewed through powerful telescopes are seen to consist of two or more stars. The measuring the angles and distances from one another of the two or more component stars of these systems, has led to the discovery that many of these very close stars are in fact acting as suns to one another, and revolving round their common centre of gravity, each of them probably carrying with it a whole system of planets and comets, and perhaps each carried forward through space like our own sun. It became then a point of great interest to determine, whether bodies so far removed from us as these systems, observed Newton's law of gravity, and to this end it was necessary to observe the angles and distances of a great number of these double stars scattered everywhere through the heavens, for the purpose of obtaining data to compute their orbits. This has been done, and chiefly by private observers; and the result is that these distant bodies are found to be obedient to the same laws that prevail in our own system.

The Nebulæ are, as it were, systems or rings of stars scattered through space at incredible distances from our star system, and perhaps from one another; and there are many of these mysterious clouds of light, and there may be endless invisible regions of space similarly tenanted. Now the nearest fixed star of our star system whose distance has been measured, is the brightest in the constellation Centaur, one of the Southern constellations, and this nearest is yet so far removed, that it takes light, travelling at the rate of about 192,000 miles per second, three years to arrive at the earth from that star. When we gaze at it, therefore, we see it only as it existed three years ago; some great convulsion of nature may have since destroyed it. But there are many bright stars in our own system, whose distance is so much greater than this, as *α* Cygni, for example, that astronomers have not succeeded in measuring it. What, then, must be the distance of these nebulæ, with which so much space is filled; every component star in which may be a sun, with its own system of planets and comets revolving round it, each planet inhabited by myriads of inhabitants! What an overpowering view does this give us of the extent of creation! The component stars of these nebulæ are so faint and apparently so close together, that it is necessary to use telescopes of great power, and with apertures so large as to admit a great amount of light, for their observation. We owe it more especially to four individuals, that telescopes have been constructed, at a great cost and with great mechanical skill, sufficiently powerful to penetrate these depths of space. Those four individuals are the Herschels, father and son, Lord Rosse, and Mr. Wm. Lassell. That praiseworthy nobleman, Lord Rosse, began his meritorious career by obtaining a First Class at this University, and has, as you know, spent large sums of money and displayed considerable mechanical genius in erecting, near his own Castle in Ireland, an instrument of far greater power than any other in the world; and with it he has observed these nebulæ, and employed skilful artists to delineate their forms: and he has moreover made the very curious discovery, that some of them are arranged in a spiral form, a fact which gives rise to much interesting speculation on the kind of forces by which their parts are held together. It were much to be wished that observations similar to these, and with instruments of nearly the same power, should be made of the Southern nebulæ also; that this generation might be able to leave to posterity a record of their present configurations. The distinguished Astronomer, Mr. Wm. Lassell, the discoverer of Neptune's satellite, has just finished at his own cost an instrument equal to the task, mounted equatorially; and I am not without hope that it may, at perhaps no very distant period, be devoted to its accomplishment. A recent communication from him to the Astronomical Society expresses satisfaction with the mounting of his instrument, and after many trials its great speculum has at last come forth nearly perfect from his laboratory.

I am, however, warned by the lapse of time, that it will not be possible for me to exhaust the whole field, the limits of which I have sketched, in which private enterprise has been assiduously at work to enlarge the bounds of astronomical knowledge. I will therefore pass at once to the two most interesting subjects which remain, the observations of Comets, and of peculiar appearances on the Sun's disc.

Of all the phenomena of the heavens, there are none which excite more general interest than comets, those vagrant strangers, the gipsies as they have been termed of our solar system, which often come we know not whence, and at periods when we least expect them: and such is the effect produced by the strangeness and suddenness of their appearance, and the mysterious nature of some of the facts connected with them, that while in ignorant times they excited alarm, they now sometimes seduce men to leave other employments and become Astronomers. Now, though the larger and brighter comets naturally excite most general public interest, and are really valuable to astronomers, as exhibiting appearances which tend to throw light on the internal structure of these bodies, and the nature of the forces which must be in operation to produce the extraordinary phenomena observed, yet some of the smaller telescopic comets are, perhaps, more interesting in a physical point of view. Thus the six periodical comets, the orbits of which have been determined with tolerable accuracy, and which return at stated intervals, are extremely useful as being likely to disclose facts, of which but for them we should possibly have ever remained ignorant. Thus, for example, when the comet of Encke, which performs its revolution in a period of a little more than three years, was observed at each return, it disclosed the important and unexpected fact, that its motion was continually accelerated. At each successive approach to the Sun it arrives at its perihelion sooner and sooner; and there is no way of accounting for this so satisfactory as that of supposing that the space, in which the planetary and cometary motions are performed, is everywhere pervaded by a very rarefied atmosphere or ether, so thin as to exercise no perceptible effect on the movements of massive solid bodies like the planets, but substantial enough to exert a very important influence on more attenuated substances moving with great velocity. The effect of the resistance of the ether is to retard the tangential motion, and allow the attractive force of gravity to draw the body nearer to the Sun, by which the dimensions of the orbit are continually contracted and the velocity in it augmented. The final result will be that after the lapse of ages this comet will fall into the Sun; this body, a mere hazy cloud, continually flickering as it were like a celestial moth round the great luminary, is at some distant period destined to be mercilessly consumed. Now the discovery of this ether is deeply interesting as bearing on other important physical questions, such as the undulatory theory of light; and the probability of the future absorption of comets by the Sun is important as connected with a very interesting speculation by Professor William Thomson, who has suggested that the heat and light of the Sun may be from time to time replenished by the falling in and absorption of countless meteors which circulate round him; and here we have a cause revealed which may accelerate or produce such an event.

In the progress of science it often happens that a particular class of observations, all at once, and owing to some peculiar circumstance, attracts very general attention and becomes deeply interesting. This has been the case within the last few years in reference to observations of the Sun's disc, which were at one time made by very few individuals, and were indeed very much neglected both by professional and amateur Astronomers. During this season of comparative neglect, there were not, however, wanting some enthusiastic individuals, who were in silence and seclusion obtaining data of great importance.

On the 1st of September last, at $11^h\ 18^m$ A.M., a distinguished Astronomer, Mr. Carrington, had directed his telescope to the Sun, and was engaged in observing his spots, when suddenly two intensely luminous bodies burst into view on its surface. They moved side by side through a space of about 35,000 miles, first increasing in brightness, then fading away; in 5 minutes they had vanished. They did not alter the shape of a group of large black spots which lay directly in their paths. Momentary as this remarkable phenomenon was, it was fortunately witnessed and confirmed, as to one of the bright lights, by another observer, Mr. Hodgson at Highgate, who by a happy coincidence had also his telescope directed to the great luminary at the same instant. It may be, therefore, that these two gentlemen have actually witnessed the process of feeding the Sun, by the fall of meteoric matter; but however this may be, it is a remarkable circumstance, that the observations at Kew show that on the very day, and at the very hour and minute of this unexpected and curious phenomenon, a moderate but marked magnetic disturbance took place; and a storm or great disturbance of the magnetic elements occurred four hours after midnight, extending to the southern hemisphere. Thus is exhibited a seeming connexion between magnetic phenomena and certain actions taking place on the Sun's disc—a connexion, which the observations of Schwabe, compared with the magnetical records of our Colonial Observatories, had already rendered nearly certain. The remarkable results derived from the comparison of the magnetical observations of Captain Maguire on the shores of the Polar Sea, with the contemporaneous records of these observatories, have been described by me on a former occasion. The delay of the Government in re-establishing the Colonial Observatories has hitherto retarded that further development of the magnetic laws, which would doubtless have resulted from the prosecution of such researches.

We may derive an important lesson from the facts above alluded to. Here are striking instances in which independent observations of natural phenomena have been strangely and quite unexpectedly connected together: this tends powerfully to prove, if proof were necessary, that if we are really ever to attain to a satisfactory knowledge of Nature's laws, it must be accomplished by an assiduous watching of all her phenomena, in every department into which Natural Science is divided. Experience shows that such observations, if made with all those precautions which long practice combined with natural acuteness teaches, often lead to discoveries, which cannot be at all foreseen by the observers, though many years may elapse before the whole harvest is reaped.

I cannot allude to the subject of Arctic voyages without congratulating the Association on the safe return of Sir Leopold M'Clintock and his gallant band, after accomplishing safely and satisfactorily the object of their interesting mission. The great results accomplished with such small means, and chiefly by the display of those qualities of indomitable courage, energy and perseverance which never fail the British seaman in the hour of need, are the theme of general admiration; but I may be permitted in passing to express some regret, that it was left to the devoted affection of a widowed lady, slightly aided by private contributions, to achieve a victory in which the honour of the nation was so largely involved,—the rather that the danger of the enterprise,—the pretext for non-interference—was much enhanced thereby, and the accessions to our scientific and geographical knowledge proportionably curtailed.

The instances to which I have alluded are only a few of many which could be adduced of an insufficient appreciation of certain objects of scientific research. Large sums are expended on matters connected with science, but this is done on no certain and uniform system; and there is no proper security that those who are most competent to give good advice on such questions, should be the actual persons consulted. It was partly with the hope of remedying these defects and of generally improving the position of science in the country in its relation to the Government, that the Parliamentary Committee of this Association was established; and it was partly with the same hope that I was induced to accept the honourable office of President of the Royal Society, though conscious at the time that there were very many far better qualified than myself to hold it. Many of those whom I am now addressing are aware of the steps which were adopted by the Parliamentary Committee, and subsequently by the Committee of Recommendations of this Association, for the purpose of collecting the opinions of the cultivators of science on the question,—Whether any measures could be adopted by Government or Parliament that would improve our position? The question was afterwards referred to and discussed by the Council of the Royal Society, who, on the 15th of January, 1857, agreed upon twelve resolutions in reply thereto. These resolutions recommend, among other things, that Government grants in aid of local funds should be applied towards the teaching of science in schools, the formation of Provincial Museums and Libraries, and the delivery of lectures by competent persons, accompanied by examinations; and finally, that some existing scientific body, or some Board to be created for the purpose, should be formally recognized, which might advise the Government on all matters connected with science, and especially on the prosecution, reduction, and publication of scientific researches, and the amount of Parliamentary or other grants in aid thereof; also on the general principles to be adopted in reference to public scientific appointments, and on the measures necessary for the more general diffusion of a knowledge of physical science among the nation at large; and which might also be consulted by the Government on the grants of pensions to the cultivators of science. I was requested to transmit these resolutions to Lord Palmerston, and also to the Parliamentary Committee of this Association. Since that period these resolutions have been discussed by that Committee; but partly because some of its most influential members have expressed grave doubts as to the expediency of urging their adoption at all, and partly from the want of a favourable opportunity for bringing them forward, nothing further has as yet been done. I thought, however, that the time was arrived at which it was only proper that I should explain the steps which had been already taken, and the actual position in which the question now stands. If it be true, as some of our friends imagine, that the recognition of such a body as has been above described, however useful it might prove if the public were disposed to put confidence in its suggestions, would only augment that feeling of jealousy which is disposed to view every application for aid to scientific research in the light of a request for some personal boon, to be bestowed on some favoured individual, then indeed its institution would not be expedient. I only wish that persons who entertain such views, would pay some attention to the working of the Government Grant Committee of the Royal Society, a body composed of forty-two persons selected from among the most eminent cultivators of science, and which is entrusted with the distribution of an annual sum of £1000, placed by Parliament at the disposal of the Royal Society at the suggestion of Lord John Russell, in aid of scientific inquiries. One of the rules of that Committee is, that no sum whatever shall be given to defray the merely personal expenses of the experimenters; all is spent on materials and the construction or purchase of instruments, except in a very few and rare instances in which travelling expenses form the essential feature of the outlay. A list of the objects to which the grants are devoted has been published by Parliament; among them are interesting investigations into the laws of heat, the strength of materials used in building, the best form of boilers, from the bursting of which so many fatal accidents are continually occurring, the electric conductivity of metals, so important for telegraphic communication, and into many other questions, in the solution of which the public generally have the deepest interest. The cost of these researches has been defrayed by these valuable grants. They have provided also for the construction of better and standard meteorological and magnetical instruments, for the execution of valuable drawings of scarce fossils and zoological specimens collected with great labour by distinguished naturalists, for the reduction and publication of astronomical observations by some of our most highly esteemed Astronomers, and for physiological researches which have an important bearing on our knowledge of the human frame. Time indeed would fail me were I to attempt to describe all the good done and perhaps evil prevented by the distribution of these grants; and yet no portion of the money can be said to be really received by those to whom it is appropriated, inasmuch as it is all spent in the various means and appliances of research; in short, to quote from a letter addressed to the Secretary of the Treasury, at a time when the grant was temporarily withheld, "by the aid of this contribution, the Government has, in fact, obtained for the advancement of science and the national character, the personal and gratuitous services of men of first-rate eminence, which, without this comparatively small assistance, would not have been so applied." I think that we were justified in terming this assistance small; for it is really so in comparison with the amount of other sums which are applied to analogous objects, but without that wholesome control of intelligent distributors, thoroughly and intimately conversant with the characters and competency of those who apply for the grants. The recognition of such a Board as has been sketched out by the Council of the Royal Society, may not lead to a greater expenditure of public money, indeed it is much more likely to curtail it; as some who now apply for aid through the interest of persons having influence with those in authority, who are generally but ill-informed on the subject-matter of the application, would hesitate long before they made a similar request to those who are thoroughly conversant with it; and it is on this account that comparatively few of the applications to the Government Grant Committee are rejected. Moreover, inasmuch as every grant passed by the proposed Board would afterwards receive the jealous scrutiny of Parliament, whose sanction must of course be obtained, I am disposed to think that were I to support the establishment of such a scientific Council, or the formal recognition by the State of some existing scientific body in that capacity, I should be advocating that which would prove a valuable addition to the Institutions of my country.

Before I finally conclude my observations on the important question I have introduced to your notice, and on which perhaps I have already said too much at the risk of wearying you, I must guard myself against one misapprehension, and that is, that we are anxious to obtain a large augmentation of the £1000 now voted by Parliament. This is by no means our wish; that annual sum is in ordinary years sufficient, and sometimes more than sufficient, and there is nothing that would be more deprecated than any large increase; but there is a very general feeling among those most competent to form an opinion on these matters, that when the well-considered interests of science and the national good demand an extraordinary outlay, such as cannot be defrayed out of the proceeds of the ordinary yearly grant,—as, for example, for surveying and exploring expeditions, for the establishment and maintenance of magnetic observatories, for the purchase of costly astronomical instruments, for expensive astronomical excursions, such as that to Teneriffe,—that the expediency of the grant is more likely to be properly investigated and tested, if referred to those whose avocations have given them the requisite knowledge, than if the concession or rejection of the proposal be permitted to depend on such accidents, as, whether this or that individual apply, or this or that statesman fill the office of Chancellor of the Exchequer.

I trust that I may be pardoned the long digression in which I have indulged, in consideration of the importance of the subject.

Having detailed some of the valuable services of our amateur Astronomers, let me not be accused of being unjust to the professional contributors to the data of that noble science. Most valuable Star Catalogues have resulted from the labours of our public Observatories, and from Greenwich in particular. There are also two Observatories which have, as it were, a *quasi* public character, viz. the Radcliffe Observatory and that of Armagh, which have contributed much to this department of Astronomy. Your former President, the accomplished and learned Dr. Robinson of Armagh, has lately presented to the astronomical world a Catalogue of the places of more than 5000 stars, and in so doing has conferred a most important benefit on his favourite science.

But it would be an unpardonable omission were I to neglect to express our gratitude to our great National Institution at Greenwich, for the manner in which it has consistently discharged the task imposed upon it by its founder and those who inaugurated its first proceedings. The duty assigned to it was "to rectify the tables of the motions of the heavens and the places of the fixed stars, in order to find out the so much desired longitude at sea, for perfecting the art of navigation;" and gloriously has it executed its task. For two centuries it has been at work, endeavouring to give to the determinations of the places of the principal fixed stars and of the heavenly bodies of our own solar system, and more especially of the Moon, the utmost degree of precision; and during the same period, the master minds of Europe have been engaged in perfecting the analytical theory, by which the many and most perplexing inequalities of the Moon's motion must be accounted for and represented, before Tables can be constructed giving the place of our satellite with that accuracy that the modern state of science demands.

The very important task of calculating such Tables has just been finished. Our able and accomplished Director of the National Observatory, Mr. Airy, had caused all the observations of the Moon made at Greenwich, from 1750 to 1830, to be reduced upon one uniform system, employing constants derived from the best modern researches; and a distinguished Danish Professor, who had been for some time engaged in calculating new Tables of the Moon, availed himself of the data so furnished. Professor Hansen happily brought to his task all the accomplishments of a practised observer, and of one of the most able analysts of modern times, combined with the most determined industry and perseverance. In the completion of it he was liberally assisted by our Government, at a time when an unhappy war had deprived the Danish Government of the means of further aiding their Professor, and a great astronomical work had been suspended for want of £300, a sum which many do not hesitate to spend on the purchase of some useless luxury. Professor Hansen's Tables are now finished and published. They agree admirably with the Greenwich Observations with which they have been compared, and the mode of their execution has been approved by those competent to express an opinion on such a subject. They have been rewarded also with the Gold Medal of the Astronomical Society, a distinction never lightly bestowed.

In paying this tribute to the merit of Professor Hansen, I must not be understood as wishing to ignore, far less depreciate, that of three very eminent geometers—Plana, Lubbock, and Pontécoulant, who have devoted years of anxious and perhaps ill-requited labour to the investigation of the Lunar inequalities, but who have never yet embodied the results in the only form useful to Navigation, that of Tables.

A curious controversy has lately arisen on the subject of the acceleration of the Moon's motion, which is now exciting great interest among mathematicians and physical astronomers. Professor Adams and M. Delaunay take one view of the question; MM. Plana, Pontécoulant, and Hansen the other. Mr. Airy, Mr. Main the President of the Astronomical Society, and

Sir John Lubbock support the conclusions at which Professor Adams has arrived. The question in dispute is strictly mathematical; and it is a very remarkable circumstance in the history of Astronomy, that such great names should be ranged on opposite sides, seeing that the point involved is really no other than whether certain analytical operations have been conducted on right principles; and it is a proof therefore, if any were wanting, of the extraordinary complexity and difficulty of these transcendental inquiries. The controversy is of the following nature:—The Moon's motion round the Earth, which would be otherwise uniform, is disturbed by the Sun's attraction; any cause therefore which affects the amount of that attraction affects also the Moon's motion: now, as the excentricity of the Earth's orbit is gradually decreasing, the average distance of the Sun is slightly increasing every year, and his disturbing force becomes less; hence the Moon is brought nearer the Earth, but at the rate of less than one inch yearly; her gravitation towards the Earth is greater, and her motion is proportionably accelerated. It is on the secular acceleration of the Moon's mean motion, arising from this minute yearly approach, that the dispute has arisen; so infinitesimally small are the quantities within the reach of modern analysis. Mr. Adams asserts that his predecessors have improperly omitted the consideration of the effect produced by the action of that part of the Sun's disturbing force which acts in the direction of a tangent to the Moon's orbit, and which increases the velocity; his opponents deny that it is necessary to take this into account at all. Had not M. Delaunay, an able French analyst, by a perfectly independent process, confirmed the results of Professor Adams, we should have had the English and Continental Astronomers waging war on an algebraical question. On the other hand, however, the computations of the ancient Lunar Eclipses support the views of the Continent; but if Mr. Adams's mathematics are correct, this only shows that there must be other causes in operation as yet undiscovered, which influence the result; and it is not at all unlikely that this most curious and interesting controversy will eventually lead to some important discovery in Physical Astronomy.

You are aware that at the suggestion of Sir John Herschel an instrument was constructed for the Kew Observatory, to which the name of Photoheliograph has been given, because it is adapted solely to the purpose of obtaining photographic representations of the appearances on the Sun's disc. Many difficulties have been encountered in the use of this instrument, but by the zealous exertions of the late Mr. Welsh, Mr. Beckley, and Mr. De la Rue, they have been overcome. It is to the last-named gentleman, so distinguished for his successful prosecution of celestial photography, that the Royal Society have entrusted a grant of money to enable him to transport the Photoheliograph to Spain, to observe the total eclipse of the Sun, which is now approaching, and great interest will attach to records of the phenomena of the eclipse thus obtained.

In Chemistry I am informed that great activity has been displayed, especially in the organic department of the science. For several years past processes of substitution (or displacement of one element or organic group by another element or group more or less analogous) have been the main agents employed in investigation, and the results to which they have led have been truly wonderful; enabling the chemist to group together separate compounds of comparatively simple constitution into others much more complex, and thus to imitate, up to a certain point, the phenomena which take place within the growing plant or animal. It is not indeed to be anticipated that the chemist should ever be able to produce by the operations of the laboratory the arrangement of the elements in the forms of the vegetable cell or the animal fibre; but he may hope to succeed in preparing some of the complex results of secretion or of chemical changes produced within the living organism,—changes, which furnish definite crystallizable compounds, such as the formiates and the acetates, and which he has actually obtained by operations independent of the plant or the animal.

Hofmann, in pursuing the chemical investigation of the remarkable compound which he has termed *Triethylphosphine*, has obtained some very singular compound ammonias. Triethylphosphine is a body which takes fire spontaneously when its vapour is mixed with oxygen, at a temperature a little above that of the body. It may be regarded as ammonia in which an atom of phosphorus has taken the place of nitrogen, and in which the place of each of the three atoms of hydrogen in ammonia is supplied by ethyl, the peculiar hydrocarbon of ordinary alcohol. From this singular base Hofmann has succeeded in procuring other coupled bases, which though they do not correspond to any of the natural alkalies of the vegetable kingdom, such as morphia, quinia, or strychnia, yet throw some light upon the mode in which complex bodies more or less resembling them have been formed.

The power which nitrogen possesses of forming a connecting link between the groups of substances of comparatively simple constitution, has been remarkably exemplified by the discovery of a new class of amide acids by Griess, in which he has pointed out a new method, which admits of very general application, of producing complex bodies related to the group of acids, in some measure analogous to the Poly-ammonias of Hofmann.

Turning to the practical applications of Chemistry, we may refer to the beautiful dyes now extracted from aniline, an organic base formerly obtained as a chemical curiosity from the products of the distillation of coal-tar, but now manufactured by the hundred-weight in consequence of the extensive demand for the beautiful colours known as Mauve, Magenta, and Solferino, which are prepared by the action of oxidizing agents, such as bichromate of potash, corrosive sublimate, and iodide of mercury upon aniline.

Nor has the Inorganic department of Chemistry been deprived of its due share of important advances. Schönbein has continued his investigations upon ozone, and has added many new facts to our knowledge of this interesting substance; and Andrews and Tait, by their elaborate investigations, have shown that ozone, whether admitted to be an allotropic modification of oxygen or not, is certainly much more dense than oxygen in its ordinary condition.

In Metallurgy we may point to the investigations of Deville upon the platinum group of metals, which are especially worthy of remark on account of the practical manner in which he has turned to account the resources of the oxyhydrogen blowpipe, as an agent which must soon be very generally adopted for the finer description of metallurgic operations at high temperatures. By using lime as the material of his crucibles and as the support for the metals upon which he is operating, several very important practical advantages have been obtained. The material is sufficiently infusible to resist the intense heat employed; it is a sufficiently bad conductor of heat to economize very perfectly the high temperature which is generated; and it may be had sufficiently free from foreign admixture to prevent it from contaminating the metals upon which the operator is employed.

The bearing of some recent geological discoveries on the great question of the high antiquity of Man was brought before your notice at your last Meeting at Aberdeen by Sir Charles Lyell in his opening address to the Geological Section. Since that time many French and English naturalists have visited the valley of the Somme in Picardy, and confirmed the opinion originally published by M. Boucher de Perthes in 1847, and afterwards confirmed by Mr. Prestwich, Sir C. Lyell, and other geologists from personal examination of that region. It appears that the position of the rude flint-implements, which are unequivocally of human workmanship, is such, at Abbeville and Amiens, as to show that they are as ancient as a great mass of gravel which fills the lower parts of the valley between those two cities, extending above and below them. This gravel is an ancient fluviatile alluvium by no means confined to the lowest depressions (where extensive and deep peat-mosses now exist), but is sometimes also seen covering the slopes of the boundary hills of chalk at elevations of 80 or 100 feet above the level of the Somme. Changes therefore in the physical geography of the country, comprising both the filling up with sediment and drift and the partial re-excavation of the valley, have happened since old river-beds were at some former period the receptacles of the worked flints. The number of these last, already computed at above 1400 in an area of fourteen miles in length and half a mile in breadth, has afforded to a succession of visitors abundant opportunities of verifying the true geological position of the implements.

The old alluvium, whether at higher or lower levels, consists not only of the coarse gravel with worked flints above mentioned, but also of superimposed beds of sand and loam, in which are many freshwater and land shells, for the most part entire, and of species now living in the same part of France. With the shells are found bones of the Mammoth and an extinct Rhinoceros, *R. tichorhinus*, an extinct species of deer, and fossil remains of the Horse, Ox, and other animals. These are met with in the overlying beds, and sometimes also in the gravel where the implements occur. At Menchecourt, in the suburbs of Abbeville, a nearly entire skeleton of the Siberian Rhinoceros is said to have been taken out about forty years ago, a fact affording an answer to the question often raised, as to whether the bones of the extinct mammalia could have been washed out of an older alluvium into a newer one, and so redeposited and mingled with the relics of human workmanship. Far-fetched as was this hypothesis, I am informed that it would not, if granted, have seriously shaken the proof of the high antiquity of the human productions, for that proof is independent of organic evidence or fossil remains, and is based on physical data. As was stated to us last year by Sir C. Lyell, we should still have to allow time for great denudation of the chalk, and the removal from place to place, and the spreading out over the length and breadth of a large valley of heaps of chalk flints in beds from 10 to 15 feet in thickness, covered by loams and sands of equal thickness, these last often tranquilly deposited, all of which operations would require the supposition of a great lapse of time.

That the mammalian fauna preserved under such circumstances should be found to diverge from the type now established in the same region, is consistent with experience; but the fact of a foreign and extinct fauna was not needed to indicate the great age of the gravel containing the worked flints.

Another independent proof of the age of the same gravel and its associated fossiliferous loam is derived from the large deposits of peat above alluded to in the valley of the Somme, which contain not only monuments of the Roman, but also those of an older Stone Period, usually called Celtic. Bones also of the Bear, of the species still inhabiting the Pyrenees, and of the Beaver, and many large stumps of trees, not yet well examined by botanists, are found in the same peat, the oldest portion of which belongs to times far beyond those of tradition; yet distinguished geologists are of opinion that the growth of all the vegetable matter, and even the original scooping out of the hollows containing it, are events long posterior in date to the gravel with flint implements, nay, posterior even to the formation of the uppermost of the layers of loam with freshwater shells overlying the gravel.

The exploration of caverns, both in the British Isles and other parts of Europe, has in the last few years been prosecuted with renewed ardour and success, although the theoretical explanation of many of the phenomena brought to light seems as yet to baffle the skill of the ablest geologists. Dr. Falconer has given us an account of the remains of several hundred Hippopotami obtained from one cavern near Palermo, in a locality where there is now no running water. The same palæontologist, aided by Col. Wood of Glamorganshire, has recently extracted from a single cave in the Gower peninsula of South Wales, a vast quantity of the antlers of a reindeer (perhaps of two species of reindeer), both allied to the living one. These fossils are most of them shed horns; and there have been already no less than 1100 of them dug out of the mud filling one cave.

In the cave of Brixham in Devonshire, and in another near Palermo in

Sicily, flint implements were observed by Dr. Falconer, associated in such a manner with the bones of extinct mammalia, as to lead him to infer that Man must have coexisted with several lost species of quadrupeds; and M. de Vibraye has also this spring called attention to analogous conclusions at which he has arrived, by studying the position of a human jaw with teeth, accompanied by the remains of a mammoth, under the stalagmite of the Grotto d'Arcis near Troyes in France.

In the recent progress of Physiology, I am informed that the feature perhaps most deserving of note on this occasion is the more extended and successful application of Chemistry, Physics, and the other collateral sciences to the study of the Animal and Vegetable Economy. In proof I refer to the great and steady advances which have, within the last few years, been made in the chemical history of Nutrition, the statics and dynamics of the blood, the investigation of the physical phenomena of the senses, and the electricity of nerves and muscles. Even the velocity of the nerve-force itself has been submitted to measurement. Moreover, when it is now desired to apply the resources of Geometry or Analysis to the elucidation of the phenomena of life, or to obtain a mathematical expression of a physiological law, the first care of the investigator is to acquire precise experimental data on which to proceed, instead of setting out with vague assumptions and ending with a parade of misdirected skill, such as brought discredit on the school of the mathematical physicians of the Newtonian period.

But I cannot take leave of this department of knowledge without likewise alluding to the progress made in scrutinizing the animal and vegetable structure by means of the microscope—more particularly the intimate organization of the brain, spinal cord, and organs of the senses; also to the extension, through means of well-directed experiment, of our knowledge of the functions of the nervous system, the course followed by sensorial impressions and motorial excitement in the spinal cord, and the influence exerted by or through the nervous centres on the movements of the heart, blood-vessels and viscera, and on the activity of the secreting organs;—subjects of inquiry, which, it may be observed, are closely related to the question of the organic mechanism whereby our corporeal frame is influenced by various mental conditions.

And now, in conclusion, I may perhaps be permitted to express the hope that the examples I have given of some of the researches and discoveries which occupy the attention of the cultivators of science, may have tended to illustrate the sublime nature, engrossing interest and paramount utility of such pursuits, from which their beneficial influence in promoting the intellectual progress and the happiness and well-being of mankind may well be inferred. But let us assume that to any of the classical writers of antiquity, sacred or profane, a sudden revelation had been made of all the wonders involved in Creation accessible to man; that to them had been disclosed not only what we now know, but what we are to know hereafter, in some future age of improved knowledge; would they not have delighted to celebrate the marvels of the Creator's power? They would have described the secret forces by which the wandering orbs of light are retained in their destined paths; the boundless extent of the celestial spaces in which worlds on worlds are heaped; the wonderful mechanism by which light and heat are conveyed through distances which to mortal minds seem quite unfathomable; the mysterious agency of electricity, destined at one time to awaken men's minds to an awful sense of a present Providence, but in after-times to become a patient minister of man's will, and convey his thoughts with the speed of light across the inhabited globe; the beauties and prodigies of contrivance which the animal and vegetable world display, from mankind downwards to the lowest zoophyte, from the stately oak of the primeval forest to the humblest plant which the microscope unfolds to view; the history of every stone on the mountain brow, of every gay-coloured insect which flutters in the sun-beam;—all would have been described, and all which the discoveries of our more fortunate posterity will in due time disclose, and in language such as none but they could command. It is reserved for future ages to sing such a glorious hymn to the Creator's praise. But is there not enough now seen and heard to make indifference to the wonders around us a deep reproach, nay, almost a crime? If we have neither leisure nor inclination to track the course of the planet and comet through boundless space; to follow the wanderings of the subtle fluid in the galvanic coil or the nicely poised magnet; to read the world's history written on her ancient rocks, the sepulchres of stony relics of ages long gone past, to analyse with curious eye the wonderful combinations of the primitive elements and the secret mysteries of form and being in animal and plant; discovering everywhere connecting links and startling analogies and proofs of adaptation of means to ends;—all tending to charm the senses, to teach, to reclaim a being, who seems but a creeping worm in the presence of this great Creation —What, I repeat, if we will not or cannot do these things, or any of these things, is that any reason why these speaking marvels should be to us almost as though they were not? *Marvels* indeed they are, but they are also mysteries, the unravelling of some of which tasks to the utmost the highest order of human intelligence. Let us ever apply ourselves seriously to the task, feeling assured that the more we thus exercise, and by exercising improve our intellectual faculties, the more worthy shall we be, the better shall we be fitted to come nearer to our God.

REPORTS

ON

THE STATE OF SCIENCE.

Report on Observations of Luminous Meteors, 1859–60. *By a Committee, consisting of* James Glaisher, *Esq., F.R.S., F.R.A.S., Secretary to the British Meteorological Society, &c.;* J. H. Gladstone, *Esq., Ph.D., F.R.S. &c.;* R. P. Greg, *Esq., F.G.S. &c.; and* E. J. Lowe, *Esq., F.R.A.S., M.B.M.S. &c.*

In presenting a continuation of the Reports on the Observation of Luminous Meteors, it will be seen that the work is now placed in the hands of a Committee, and it is with sincere regret that in presenting their first report, they have to announce the loss of Professor Powell, who died on the 11th of June, 1860. The preceding twelve reports were carried on solely by Professor Powell, but from the further prosecution of this labour he felt compelled to retire some little time since on account of failing health, having made arrangements for the continuation of the reports. Within the past year there does not seem to have been any unusual exhibition of meteors, either in August or in November; and there is little to be added to the observations themselves; in one instance only was the same meteor seen by two different persons, viz. that observed at Wrottesley Observatory and at Baldoyle (county Dublin), on March 10, 1860: this meteor was remarkable for its form and for its variation in colour, as noticed by both observers. It is much to be regretted that the observations of this meteor yet collected are insufficient to trace its path, velocity, &c.; it is scarcely possible that so remarkable a meteor, visible from points so distant, can have passed unnoticed, and it is very desirable that if any observations may have been taken of it, that they should be forwarded to the Committee, for the purpose of being submitted to calculation.

M. Julius Schmidt, now of the Royal Athens Observatory, in a communication to M. W. Haidinger of Vienna, read by the latter at Vienna the 6th of October, 1859, before the Imperial Academy, has made some valuable observations upon some phenomena relative to the luminous tails of meteors, of which a *résumé* is given in the Appendix. An interesting paper has appeared in the Philosophical Magazine, April 1860, "On Luminosity of Meteors from Solar Reflexion," by R. P. Greg, Esq.; a brief analysis is given in the Appendix. In the Journal of the Franklin Institute there is a very interesting account of a large meteor seen over a large extent of country by daylight, on November 15, 1859; an abstract of this paper also appears in the Appendix.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1859.	h m s				
Sept. 25	8 0 p.m.	Globe	Large	No	Slow
Sept. 27	8 15 p.m.	Globe form, twice the size of 1st mag. *	Blue and bright.	Leaving a streak	Rapid. Duration 0·1 sec.
Sept. 27	8 15 45	Equal to 2nd mag. star, as a spark.	Blue	No streak or separate sparks.	Slow. Duration 0·9 sec.
Sept. 27	9 25 p.m.	=2nd mag. *	Blue	Slight streak	
Oct. 15	6 30 p.m.	= 1st mag. *	Reddish bright.	A streak composed of separate stars.	Duration 0·3 sec.
Oct. 21	2 11 a.m.	= to 2nd mag *	=to 1st mag.*, orange.	Leaving a small mass of separate stars in its track.	Rapid. Duration 0·1 sec.
Oct. 21	5 45 p.m.	Larger than ♃		Long train	Lasting 2 or 3 secs.
Oct. 22					
Oct. 23	7 49 15	Three times the size of a 1st mag. star. Planetary in appearance.	*Orange*, and three times brightness of 1st magnitude star, increasing in brightness for two-thirds of its path, then suddenly decreasing to the size of a 2nd mag. star, changing its colour to a *bluish white*; no alteration during the latter portion of its path; suddenly extinguished.	No sparks	Slow. Duration 2 seconds.

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
....	Much cloud and strong lightning in W. and W.S.W.	Highfield House.	E. J. Lowe	Mr. Lowe's MS.
From near α Pegasi, passing through γ Aquarii to about δ Capricorni.	Moving on a slight curve.	Ibid...............	Id.	Ibid.
From γ Aquarii to δ Capricorni	....	Ibid...............	Id.	Ibid.
Moved downwards from below Aquarius.	The meteors to-night gave a point of divergence in Cassiopeia.	Ibid......	Id.	Ibid.
Moved from under ε Ursæ Majoris, from the direction of γ Ursæ Majoris and fading away 2° beyond η Ursæ Majoris, having passed within 30′ of this star.	Increased in brilliancy and disappearing at maximum brightness. Much cloud. Aurora Borealis.	Ibid...............	Id.	Ibid.
Moving horizontally from E. to W. and crossing over ξ Ursæ Majoris.	Very bright for its size. During the evening Aurora Borealis and lightning.	Ibid...............	Id.	Ibid.
Passed between Cassiopeia and the Pole Star, going towards N.E. Its course was a line from γ Cephei to E group of Camelopardus.	At Highfield House at the time there was Aurora Borealis, lightning and snow.	Diss, Norfolk ...	Correspondent...	Ibid.
....	Many meteors. Lightning and snow.	Highfield House.	E. J. Lowe	Ibid.
From the direction of Capella, starting at No. 36 Aurigæ, and fading away midway between θ Ursæ Majoris and No. 26 in the Lynx in a space devoid of stars.	A singular meteor.	Ibid...............	Id.	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1859.	h m s				
Oct. 23	8 1 p.m.	As a spark	Small	No sparks left	Very rapid; almost instantaneously.
Oct. 23	8 32 p.m.	= 2nd mag. *	Colourless	No streak or train	Rapid. Duration 0·2 sec.
Oct. 23	11 46 30	= 2nd mag. *, star-like.	Bright blue	A streak left in its track.	Rapid. Duration 0·2 sec.
Oct. 25	2 0 a.m.	= 2nd mag. *	Blue	With a train	Rapid. Duration 0·2 sec.
Nov. 2	Between 7 & 8 p.m.				
Nov. 2	12 45 a.m.	= 1st mag. *, appeared as a flash.			Rapid
Nov. 3	2 3 a.m.	= 3rd mag. *	Colourless	Streak	Rapid
Nov. 3	2 4 a.m.	= 3rd mag. *	Colourless	Streak	Rapid
Nov. 13	2 50 a.m.	= 2nd mag. *	Colourless	Streak	Very rapid
Nov. 13	2 52 a.m.	= ♃	Brilliant orange scarlet.		Instantaneous
Nov. 13	2 40 a.m. till 3 a.m.				
Nov. 15	8 55 p.m.	= in size to ♃. Globe meteor.	Blue, bright	Without sparks or train till it burst, then broke into two or three small fragments and disappeared.	Slow. Duration 0·4 sec.
Nov. 20	8 0 p.m.				
Dec. 5	5 2 p.m.	Twice the size of ♃	Colourless		Slow
Dec. 5	6 30 p.m.	= 1st mag. *	Colourless		Slow
Dec. 5	9 25 p.m.	= 1st mag. *			

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
From β Andromedæ towards S. downwards at an angle of 45°.	Slight Aurora Borealis and distant lightning.	Highfield House.	E. J. Lowe	Mr. Lowe's MS.
From above ι Draconis to near τ Herculis coming from the direction of Polaris.	....	Ibid...............	Id.	Ibid.
Passed 15' E. of both ι and χ Ursæ Majoris crossing over the star 36 in the Lynx, moving over 20° of space perpendicularly down.	....	Ibid...............	Id.	Ibid.
Perpendicularly down from near No. 25 Canes Venatici.	Temperature 24°·5 at 4 feet, 18°·0 on the grass.	Ibid...............	Id.	Ibid.
....	Many large meteors, chiefly in N.E.	Ibid...............	Capt. A. S. H. Lowe.	Ibid.
In N. about 20° below the Pole Star.	Appeared, disappeared, and reappeared four times in rapid succession, but never moved its situation.	Ibid...............	Id.	Ibid.
Fell down from under Polaris at an angle of 80°, and fading away as it reached the Milky Way.	....	Observatory, Beeston.	E. J. Lowe	Ibid.
From the zenith towards β Persei.	....	Highfield House.	Id.	Ibid.
Perpendicularly down through Cassiopeia.	....	Ibid...............	Id.	Ibid.
3° above the N. horizon, seen through a cloud.	Lightning in N. at the time.	Ibid...............	Id.	Ibid.
....	12 meteors. Clouds numerous all evening and night, and this, added to a full moon, caused most of the meteors to be invisible. Faint Aurora Borealis.	Ibid...............	Id.	Ibid.
Fell down in N.W. from 20° above the horizon, disappearing 10° above the horizon.	An auroral arch at the time.	Ibid...............	Id.	Ibid.
....	Several meteors ...	Ibid...............	Id.	Ibid.
Down in N.W. across η Ursæ Majoris only, moving over 5° of space.	....	Ibid...............	Id.	Ibid.
Fell down in W. from the altitude of 45°.	....	Ibid...............	Id.	Ibid.
Fell perpendicularly down in S.W. from the altitude of 40°, moving over 5° of space.	....	Ibid...............	Id.	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1859. Dec. 7	h m 7 0 p.m.	Larger than Jupiter, star-like.	Reddish	Long streak	Very rapid. Duration 2 secs.
Dec. 14	9 20 p.m.	=2nd mag. *	Orange	Sparks	Rapid. Duration 2 secs.
1860. Jan. 2	8 10 p.m.	= ♃ in size.........	....	....	....
Jan. 24	9 28 p.m.	Increased rapidly until four times the apparent size of Jupiter.	Blue...........	Train of separate sparks...	Slow. Duration 7 secs.
Jan. 24	From 9 to 10 p.m.	....	....	....	....
Feb. 24	7 40 p.m.	=Venus	....	With tail	....
Mar. 2	10 40 p.m.	=four times size of ♃	Bright	Long tail	Slow....................
Mar. 10	8 40 p.m.	= Venus..............	Bright as Venus. Colour of Venus.	Moderate speed, trail of sparks left in its track for 3 seconds after the meteor had vanished.	....
Mar. 14	8 45 p.m.	Six times size of Jupiter.	Very bright, almost like lightning in appearance. Red in colour.	Burst into fragments	Moderate speed ...
Mar. 21	7 15 p.m.	= Venus.............	Brighter than Venus.	....	Slow....................
Mar. 21	7 40 p.m.	= Venus..............	Brighter than Venus.	....	Slow....................
April 1	8 10 p.m.	=2nd mag. *	Yellow.........	Slight tail	Slow....................
April 17	Between 10 & 11 p.m.	....	....	....	....

Observations of Luminous Meteors

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1857. Aug. 16	11 45 p.m.	Equal to the size of Jupiter, but very superior to that planet in brightness.	Bluish white..	It was accompanied by a train.	Slow, but its duration was short, as it did not travel above 5° or 8°.
1858. Aug. 8	8 45 p.m.	Very bright, and about the size of Jupiter.	Blue...........	It left a faint yellow train of light in its path.	Moderate............
Aug. 8	9 15 p.m.	Small but bright......	Blue...........	Left a train visible for several seconds.	Very slow ....
Aug 8	9 38 p.m.	Small, about size of Saturn.	Moderately bright.	No train	Rapid in its motion; visible for about 0·5 second only.

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
From 45° above the E. horizon, moved down at an angle of 40°.	....	Observatory, Beeston.	R. Porter	Mr. Lowe's MS.
From the Dragon's Head, fell down at an angle of 40° towards W.	Snow showers	Ibid.	E. J. Lowe ...	Ibid.
Fell down from 12° above the horizon in S. by E.	Gale..................	Ibid.	Id.	Ibid.
From the direction of Polaris, passing midway between δ and γ Leonis, crossing ρ Leonis, and fading away near 43 Leonis.	....	Ibid.	Id.	Ibid.
....	Six meteors seen ...	Ibid.	Id.	Ibid.
Crossed down the tail of the Great Bear.	....	1 mile W. of Beeston.	Miss C. Drége...	Ibid.
In S.W., falling towards W.; half-way to zenith when first seen.	....	1 mile N.E. of Beeston.	Mrs. R. Felkin...	Ibid.
From 60° altitude W. by N., falling down towards W. at an angle of 75°.	....	Observatory, Beeston.	Mr. R. Porter (assistant obs.)	Ibid.
Fell down in Leo	After the fragments were thrown out, the meteor still moved on of the same size and brightness for a short distance.	Highfield House.	Capt. A. S. H. Lowe.	Ibid.
In S., fell down a long distance towards W., and passing through Orion.	....	Observatory, Beeston.	Miss Lucy White	Ibid.
In S.	Similar to the last.	Ibid.	Mr. R. Porter (assistant obs.)	Ibid.
From α Aurigæ to Venus, over which planets it crossed, and then immediately vanished.	Increased in size at last.	Ibid.	Id.	Ibid.
....	Several meteors moving very rapidly.	Ibid.	E. J. Lowe	Ibid.
from various Observers.				
It started 10° from the zenith, a little west of the Milky Way.	....	Greenwich	Henry C. Criswick.	MS. communication.
Fell down N. from about 45° from the horizon; disappeared about 5° from horizon.	It was very light at the time, and the stars in the path of the meteor could not be seen.	Blackheath	Id.	Ibid.
Started from a point 10° below α Aquilæ, taking a westerly course.	....	Ibid.	Id.	Ibid.
Fell perpendicularly from 25° above α Virginis to a little south of that star.	....	Ibid.	Id.	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1858. Aug. 8	h m 9 44 p.m.	Equal in size to a 4th mag. *	Very bright	It left a thin train visible for about 1 sec.	Slow
Aug. 8	9 52 p.m.	Rather larger than Saturn.	Remarkably bright.	No train	Very rapid
Aug. 8	9 55 p.m.	Size of a 3rd mag. *	Very bright. Blue.	A very bright train, visible for 3 secs. after the extinction of the nucleus.	Slow
1859. Aug. 26	8 24 p.m.	Six times the size of α Lyræ.	Much brighter than α Lyræ.		
Aug. 30	10 14 p.m.	As bright as Capella			Visible for about 3 or 4 secs.
Aug. 31	7 53 p.m.		Brighter than any star then visible.		
Sept. 22	Between sunset and 11 p.m.	Many shooting stars			
Sept. 24	Evening	Many shooting stars			
Sept. 28	10 20 p.m.	Larger than Jupiter	Blue	None	
Oct. 22	7 38 p.m.				
Oct. 23	8 15 p.m.		Very bright		Visible for several secs.
Oct. 27	9 9 p.m.	As large as Capella			
Oct. 29	7 56 p.m.				Very rapid
Nov. 7	9 33 p.m.		As bright as Capella.		
Nov. 9	5 30 a.m.	About 2° long	Colour of red-hot iron; its illuminating power very great.	No sparks were seen	Its greatest brilliancy lasted for 30 seconds, but it remained visible for 10 minutes.
Nov. 30	9 40 p.m.		Faint yellow	They left a train, similar to a faint streak.	

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
Fell from a little E. of the Great Bear constellation diagonally towards the N.W., disappearing about 20° above the horizon.	....	Blackheath	Henry C. Criswick.	MS. communication.
From 35° above the due S. horizon; it went by W. to the horizon.	Just before disappearing below the horizon I distinctly saw it separate, giving at the same time a report like that of a distant rifle.	Ibid................	Id.	Ibid.
From 40° above the E.S.E. horizon to S.E., disappearing 25° above the horizon.	....	Ibid................	Id.	Ibid.
Fell perpendicularly from near α Ophiuchi to within 15° of the horizon.	....	Wrottesley Observatory.	W. P. Wakelin.	Ibid.
Fell from 10° above η Ursæ Majoris, between η and ζ, to within a degree or two of 12 Canum Venaticorum.	This meteor paled twice, and attained its maximum brightness just before its disappearance.	Ibid................	Id.	Ibid.
From near α Cassiopeiæ diagonally towards a point north of α Persei.	....	Ibid................	Id.	Ibid.
About Pleiades, moving W. to E.	....	Ballater	J. H. Gladstone.	Ibid.
....	....	Elgin	Id.	Ibid.
Northern hemisphere; it fell from W. to E. through 25°, descending from an altitude of 35° to about 25°.	....	Fort William, Scotland.	Mrs. J. H. Gladstone.	Ibid.
A few degrees S.W. of γ Pegasi.	It attained its maximum brilliancy immediately before it disappeared.	Wrottesley Observatory.	F. Morton.	Ibid.
It descended vertically from the constellation Draco to within 10° or 15° of the horizon.	....	Ibid................	Id.	Ibid.
In N.E. from about 35° or 25° altitude.	....	Ibid.	W. P. Wakelin.	Ibid.
From midway between the constellation Lyra and Hercules, at an angle of 45° to S.	....	Ibid.	F. Morton	Ibid.
From near β Pegasi, at an angle of 45°, to within 10° of the S.W. horizon.	....	Ibid.	Id.	Ibid.
About the same altitude as the Pleiades, and some 8° to the south.	As it paled it got gradually shorter and wider; it at last looked like a faint cloud.	Ibid.	The under-gardener at Lord Wrottesley's, the times by F. Morton.	MS.
From Capella to Sirius	They were three in number.	Manchester	G. V. Vernon.	

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1859.	h m				
Dec. 3	7 10 p.m.	Its brightness was equal to that of a * of the 1st mag.	Same colour as Rigel.	No apparent train ………	Very rapid ………
Dec. 13	10 35 p.m.	2nd mag. …………	White ………	None ………………………	………………………
1860.					
Feb. 11	11 20 p.m.	………………………	Scarlet, pea-green.	The outer portion of the stream was composed of bright scarlet scintillations.	About 5 or 6 secs.
Feb. 16	9 30 p.m.	………………………	Very brilliant.	………………………	………………………
Mar. 3	9 20 p.m.	………………………	Very bright and of a reddish colour.	………………………	………………………
Mar. 10	9 20 p.m.	The appearance gave the impression of 3 feet in length. Its form was strictly defined, the front portion being in shape like the head of a lily, with a petal-shaped outline. From this it diminished gracefully to the tail, not in straight-sided lines, but in curves. The tail was the smallest, and apparently the most concrete portion of the whole.	Bright as brightest moonlight. Colour distinct and varied, the head pearly white, the tail bright ruby, with reddish-brown extremity, and the middle portions marked by bands of various shades of colour.	No train of sparks ………	Lasted 5 seconds slow.
Mar. 10	9 32 p.m.	A bar of light in length equal to moon's diameter, its breadth ⅙th of its length.	At first its colour was pure white, and as bright as Sirius. In its full the colour changed to green, and afterwards to a deep glowing crimson.	It left behind a train of pale yellow light.	The whole time was 2 secs.

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
It fell from near the zenith, passing through Orion's Belt, and disappeared when on a level with Rigel.	....	Manchester	G. V. Vernon.	
Passing nearly horizontally through Ursa Major.	....	London	Mr. W. Grubb.	
At an elevation of about 600 feet its direction was S.S.E.	After dropping perpendicularly for a short distance it separated itself into about eighteen globular masses of different colours, some about 8 or 10 inches in diameter, and the others from 1 to 3 inches.	Sidmouth	T. H. S. Pullen.	
It fell from an elevation of 60° and N.N.E., and disappeared in the N.E. at an elevation of about 10°.	....	Osborne	J. R. Mann.	
About 50° in a N.E. direction.	After falling about 50°, it burst into a number of sparks, like a rocket.	Coleraine.		
The direction was that of a line drawn from Orion's Belt, through the Pleiades, and onward to the W. of Cassiopeia, disappearing in the N.E. portion of the hemisphere.	About 30 secs. after the disappearance of the meteor there was a low rumbling thunder in the N.E., which continued fully 2 mins.	Baldoyle (county Dublin).	J. P. Culverwell, Esq.	Mr. Lowe's MS.
It was seen at an altitude of 45°, and darted perpendicularly between the Pleiades and Algol to the horizon.	The stars for 15° on each side of its path were paled as by the presence of the full moon.	Wrottesley Observatory.	J. H.	MS. communication.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1860.	h m				
Mar. 10	9 50 p.m.	It appeared about $\frac{2}{3}$rds of the size of the moon.	Very bright, at first purple-red and then green, = Venus.		Visible for a second or two.
Mar. 15	2 0 a.m.		Very bright		2 or 3 secs.
April 14	9 4 p.m.		Equal to Aldebaran in brightness.		
April 26	7 52 p.m.		At first brilliant white, and afterwards purple-red.	It left a very luminous tail behind it.	It was visible about a second.

APPENDIX.

No. 1.—In the Journal of the Franklin Institute, Philadelphia, February 1860, is a collection of observations of a very remarkable meteor seen by daylight, on November 15, 1859, by Benjamin P. Marsh, Esq.

This meteor made its appearance at about half-past 9 o'clock A.M. (New York time), the weather being perfectly clear, and the sun shining brightly.

It was seen at Salem, Boston, and New Bedford, Massachusetts; Providence, Rhode Island; New Haven, and many other places in Connecticut; New York City; Paterson, Medford, and Tuckerton, New Jersey; Dover, and other places in Delaware; Washington City; Alexandria, Fredericksburg, and Petersburg, Virginia.

It was *heard* at Medford, New Jersey, and at *all* places in that State, south of a line joining Tuckerton and Bridgeton, and throughout nearly the whole of Delaware.

With perhaps two or three exceptions, it was *not seen* by any one in New Jersey, south of the Camden and Atlantic Railroad; that is to say, *throughout the very region where the report was loudest.*

Many persons there saw a momentary flash of light "like the reflexion of the sun from a looking-glass," but could not tell where it came from. The appearance of the meteor as seen at many places is described, and the results from their discussion are as follows:—

1. The inclination of the meteor's point to the vertical was probably about 35°, and the direction of its motion nearly west. The observations at Medford and Petersburg indicate a much more southerly movement, but those of Washington, Alexandria, and Dover, require it to have been almost due west.

2. The column of smoke was near 1000 feet in diameter, and its base was

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
It fell at an inclination of N.W. to W.	It travelled about 15° and then burst; it appeared at first as though the moon had fallen to the earth.	Bradford	M. D. W. W. M. E. M. C. J. C. C. W.	
In the N. 45°	It appeared stationary, but increased in brightness for 2 or 3 seconds, when it suddenly disappeared.	Torquay	E. Vivian.	
It darted from a point halfway between the Pleiades and ζ Persei to a point about one-third of the distance from Aldebaran to ι Aurigæ.	Its path was concave to the horizon.	Wrottesley Observatory.	J. H.	MS. communication.
It fell from the zenith to the N.W.	....	Manchester	G. V. Vernon.	

vertical about four miles north of Dennisville, at a height of near eight miles, which may be assumed to be the approximate position of one point in the meteor's path. The height is inferred not merely from the angular elevations of the smoke as seen from different points, but from the interval between the flash and the report, as observed at Beasley's Point. This position assigned to the base of the cloud, from local reports, coincides pretty nearly with that indicated by distant observations.

At New Haven, latitude 40° 18′ 18″, longitude 72° 55′ 10″, at an elevation of 6°, the bearing was S. 35° 34′ W.; and at Alexandria, latitude 38° 49′, longitude 77° 4′, at an elevation of 10½°, it was N. 76½° E. These directions meet half a mile west of Dennisville in latitude 39° 11½′, longitude 74° 50½′; the line from New Haven having a vertical height at this point of 22½ miles, and that from Alexandria 24½ miles. Continuing the path, as observed at Alexandria, down to 9½° elevation, we have corresponding azimuth 76¼°, and the lines then meet half a mile north-west of Dennisville at a height of 22½ miles; but this makes the nearest point in the meteor's path twenty-four miles from Beasley's Point, and consequently the interval there between the flash and the report two minutes instead of one, as observed. Besides, the observations on the smoke show pretty clearly that the minimum height at Dennisville could not have exceeded ten miles. We must therefore conclude the meteor's actual position to have been several miles east of that indicated by these distant observations.

3. On the above supposition, the meteor's path would reach the earth near Hughesville, on the north-western boundary of Cape May County, in which vicinity, or perhaps still further west, it is probable that the meteor or some of its fragments will yet be found.

4. Some observers must have seen the meteor at a height of more than

100 miles; and, to have completed its path within their estimates of time, it must have had a velocity of from thirty to fifty miles per second.

The extreme shortness of the time occupied in its flight, is proved not merely by the estimates of several observers, but by the failure of people in the vicinity of the explosion to distinguish the source of the sudden flash of light seen by them, and by the impression of even the most distant observers that it fell very near them.

5. The sound was explosive, and *not* caused by the falling in of the air after the meteor. In the latter case it must have been continuous and uninterrupted, but the testimony of Dr. Beasley and others shows that it ceased entirely and then began again.

Supposing the meteor to have been a stony mass, we may, perhaps, consider the explosion to have consisted of a series of decrepitations caused by the sudden expansion of the surface, the whole time of flight not being sufficient to allow the heat to penetrate the mass. At the forward end these explosions would take place under great pressure, which may account for the loudness of the sound.

6. The estimated duration of the sound at Beasley's Point was not less than one minute, indicating that the most distant point of the explosion was not less than twelve miles further from that place than its nearest point. Comparing this with the position of the assumed path, we find that, during the explosion, the meteor must have travelled fifteen or twenty miles, occupying about a second of time.

7. The explosions were very numerous, arranged in two series, the whole occupying only half a second of time, but the individual sounds were distinguishable, because of the different distances they had to travel to reach the ear. The velocity of the meteor being more than 100 times that of sound, the reports must have come in the order of distance and *not* in the order of their occurrence, causing the end of the explosion to be heard before the beginning. The faint rushing sounds first heard by Mr. Ashmead must have had their origin below the explosion, and been caused by the flight of the fragments towards the earth. If the direction of the *first faint* sound could be indicated by persons further west, it might serve to point to the place where the fragments fell.

8. The meteor lost its luminosity with the explosion or shortly after, and hence was not seen by persons in Cape May County and vicinity, it being too much overhead to come within the ordinary range of vision, and the time of flight being too short to allow them to direct their eyes to it after seeing the flash.

If the heat be due to the resistance of the air, it must be principally developed at the surface of the forward half of the meteor. Consequently most of the explosions must occur then, and the force of each be directed backward, tending to check the velocity of the mass. In fact, we may perhaps consider the series of explosions to be merely one of the forms of the atmospheric resistance. This must increase rapidly with the density, although it may be insufficient to account for so great a reduction of speed as would entirely destroy the luminosity of the meteor before it reached the earth.

9. From the tremendous force of the explosion, and from the fact that this meteor was seen by persons who were not within 200 miles of any part of its path, as at Salem, Massachusetts, and Petersburg, Virginia, we must certainly conclude that it was of very considerable size; but we seem to have no data for any approximation to its actual dimensions. It was certainly heated to a most intense brightness; and the experiments of Professor J. Lawrence Smith, detailed in Silliman's Journal, vol. xix. fol. 340, second

series, in which he found that a piece of lime, less than half an inch in diameter, in the flame of the oxyhydrogen blowpipe, had, when viewed in a clear evening, at the distance of half a mile, an apparent diameter twice that of the full moon, show conclusively that no reliance can be placed upon calculations founded upon the apparent diameter of bodies in a state of incandescence.

10. The apparent form of the meteor, that of a cone moving base foremost, may have been due to its great angular velocity, combined with the effect of irradiation above referred to. The impression made upon the eye by the incandescent body itself, would doubtless be greater than that made by the sphere of light surrounding it. Consequently we should continue to see the body itself after the impression of the mere glare had faded away; so that the apparent diameter of the end of the tail may represent the actual angular diameter of the body.

11. The invisibility of the meteor to persons at Philadelphia and vicinity, was no doubt due to the position of the sun, the direction of which then coincided with that of the meteor.

No. 2.—Abstract of a paper by R. P. Greg, Esq., F.G.S., in the Philosophical Magazine, April 1860, "On Luminosity of Meteors from Solar Reflexion."

With reference to the cause of the luminosity of shooting stars, the author proposes to prove that their luminosity cannot arise from solar reflexion, a theory partially supported by Sir J. Lubbock and others. He observes that the very sudden appearance and disappearance of shooting-stars and small meteors, and their general resemblance on a small scale to comets which shine by solar reflexion, certainly favour the idea, either that suddenly entering the cone of the earth's shadow they are instantly eclipsed, or conversely, become visible as they emerge from it; or *secondly*, previously self-luminous in planetary space, they may become suddenly extinguished on entering the denser atmosphere of the earth; or *thirdly*, they may suddenly become visible and luminous only on entering the earth's atmosphere by friction and compression, by rapid absorption of oxygen and sudden chemical action, or by electrical excitation.

The author then refers to Sir J. Lubbock's paper in the Philosophical Magazine for February 1848, and shows by a different treatment how unlikely, if not impossible, it is that ordinary shooting-stars (those not showing symptoms of active ignition within the lower limits of the earth's atmosphere) can ever shine by reflected solar light; and this simply from the fact that they would be too far off for us to observe such small bodies, at even the *minimum* distance at which (at certain times and places on the earth's surface when and where we know they are very frequently seen) they actually could be so visible; and concludes his paper by remarking that, if his calculations, &c. be correct, the majority of shooting-stars do not shine by reflected light.

No. 3.—M. Schmidt on the Luminous Trains left by Meteors, &c.

M. Schmidt repeats an observation of M. Faye's in the 'Comptes Rendus,' vol. xxxii. p. 667, relative to the small amount of moveability in the tails or luminous trains not unfrequently left by meteors, which seems to prove that the former must be found in the atmosphere belonging to and surrounding the earth, and not in the firmament which lies beyond it. M. Faye observed one of these tails through the telescope, and he saw it "lingering for more than three minutes, without changing its place very perceptibly.—Other observers have observed them to remain for more than seven minutes." M.

Schmidt remarks on the strangeness of this stationary condition of the luminous trains of meteors, likewise on the cloud-like appearances generally left by detonating meteors even in the day-time, when we come to consider the enormous velocity of the meteors themselves through the higher regions of the atmosphere; but he says, "we must recollect an easy and interesting experiment, by which we may obtain a similar result. If you take a common lucifer match, still burning, or when it is just about to become extinguished, and throw it from you in any direction, either quickly or slowly, you will in many cases perceive, either a straight immoveable line, or an undulating or curling line of white-grey smoke, standing still in the air, if the air is calm and not in motion."

M. Schmidt observes how important observations, whether telescopic or otherwise, are respecting the tails of meteors,—1st, as regards their proper motion; 2nd, the downward curvature sometimes exhibited by them, and the way in which they break up and disperse; and 3rd, the means they may afford of ascertaining by parallax their height above the earth, a matter of very great importance for ascertaining at what heights the atmosphere ceases to have any influence.

M. Schmidt then proceeds to cite a number of instances from his own catalogue of meteors, where tails have been observed of long duration, or as offering very peculiar appearances: *e. g.*

1664. Aug. 3. A very large meteor with curved tail, seen at Papa, Hungary.

1791. Nov. 11. At Göttingen and Lilienthal, a meteor left an undulating tail of a shining white colour, in parts alternately showing the prismatic colours; then became more curved, and turned into vapour of a pale yellowish colour before finally disappearing.

1798. Oct. 9. Brandes witnessed at Göttingen how the tail of a bright shooting-star bent itself within 15 seconds like a bow.

1840. July 30. Ditto at Vienna, in 15 seconds also.

1845. Oct. 24. Schmidt observed at Bonn the change in the form of the tail of a meteor in 4 minutes; it became severed and bent, and dissolved into small grey clouds. The whole mass moved 1° from its original place at final disappearance.

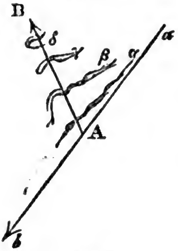
1853. Oct. 26. A large meteor seen in Pomerania, left behind it a spiral tail 3° long, which contracted soon into a ball, and again passed into a spiral curve, finally assuming the shape of a capital Z.

1854. Aug. 1. At Göttingen, a fine meteor left behind a bright tail 3′ wide and 2° in length, lasted 8 or 9 minutes after dividing itself into three oval balls, and showing at first uneven undulations or knots, while the tail itself shortened and became more like a W. Whilst these changes took place in the tail, the whole mist-like mass moved along the sky in a nearly opposite direction to the motion of the fireball itself; the tail had thus moved 9° in 8 minutes.

1859. Aug. 9, 10, 11. During these three nights, M. Schmidt at Athens succeeded in observing, on four different occasions, the curving of meteor-tails through the telescope. The whole time, in three cases of visibility, was 170″, 140″, and 220″ respectively; in one case only 10″ or 12″. The curvature of the tail began to be perceptible almost directly after the meteor vanished, and the proper motion in one direction very decided. In one of these cases, viz. on Aug. 11, a bright orange-coloured shooting-star left a tail visible to the naked eye 4″ or 5″, but through the telescope 220″; the direction about from E.N.E. to W.S.W. The following figure shows the real motion of the tail, compared with the apparent motion of the shooting-star.

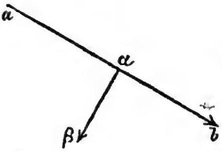
The tail finally broke up into a number of small fragments.

Fig. 1.



a b, the apparent motion of the shooting-star.
α, tail at end of 5th second.
β, tail at end of 12th second.
γ, tail at end of 180th second.
δ, tail at end of 220th second.
A B, apparent motion of the tail nearly at right angles to *a b*.

Fig. 2.



Aug. 9. Representing, after another meteor, a similar movement of tail as compared with the meteor itself.

M. Schmidt states that credible cases, where the tails of meteors and shooting-stars remain visible longer than 5 seconds, are very rare and isolated. He cites thirty-nine instances from his own catalogue, of which we select seven instances of longest duration.

1751.	May	26.	$3^h\ 30^m$......	Kraschina (Agram meteoric iron fall).
1803.	Oct.	10.	1^h	On the high seas.
1840.	July	30.	15^m......	Vienna.
1847.	Jan.	10.	10^m......	Vienna.
1847.	Nov.	10.	10^m......	Benares.
1853.	Aug.	26.	10^m......	Mazzow.
1856.	Oct.	29.	30^m......	Laybach.

Among the thirty-nine instances given by M. Schmidt, there were more than one instance of the tail winding or doubling itself up, nay, of even vanishing and then re-appearing.

Duration of Meteors.

M. Schmidt also offers further remarks on the duration of meteors, and he observes how rarely they are visible for more than 1 second; that 0′ 2″ to 1′ 5″ is the usual time of visibility; the practised observer knows that the majority in fact of shooting-stars only shine during the fraction of a second.

In all probability the short moment during which the light shines is at the same time the moment of its partial and final extinction.

The time during which a shooting-star is visible is a subject for the art of more refined observation, and M. Schmidt hopes that much attention will be directed "towards determining the duration with regard to colours and any anomalous motions of meteors." In his treatise on Meteors, p. 15, M. Schmidt states how long the tails or luminous trains of meteors remain visible, with regard to *colour*, viz. as follows:—

	sec.		Mean error.
With white meteors, the mean	=1·00	in 24 observations....	0·05
With yellow meteors, the mean	=1·51	in 18 observations....	0·15
With green meteors, the mean	=1·96	in 12 observations....	0·29

On the other hand, at p. 50, the time during which tails are visible upon the whole number, with regard to these different colours:—

sec.

Time of duration for the white shooting-stars, mean =0·85 in 64 observations. A.D. 1849.

Time of duration for the yellow shooting-stars, mean =0·90 in 80 observations. A.D. 1849.

Time of duration for the yellowish-red shooting-stars, mean =1·28 in 14 observations. A.D. 1849.

Time of duration for the green shooting-stars, mean =1·60 in 5 observations. A.D. 1849.

Time of duration for the mist-like or nebulous shooting-stars, mean =0·91 in 12 observations. A.D. 1849.

Likewise in the year 1850 the longer duration of the coloured meteors showed itself in the following proportional means:—

secs.

Duration of the white =1·16 in 12 observations.

Duration of the yellow =1·25 in 8 observations.

Duration of the yellowish red =1·41 in 6 observations.

If we consider the time during which the light of the meteor itself lasted without regard to any other phenomena, we find in his catalogue the following instances which show that in the case of many thousand observations it is very rare that a shooting-star or meteor remains visible for more than 5 seconds.

Date.	Duration. secs.	Place of observation.
1783. August 18	60*	London.
1842. November 1	10	Hamburg.
1842. November 7	10	Hamburg.
1842. November 21	8	Hamburg.
1843. September 19	7	Hamburg.
1843. September 22	9	Hamburg.
1844. August 11	6	Hamburg.
1846. August 10	8	Bonn.
1847. November 29	8	Bonn.
1851. September 26	11	Münster.
1852. November 3	10	Münster.
1854. August 1	35	Göttingen.
1854. December 8	8	Vienna.
1856. October 29	12	Laybach.
1857. ?	23	Vienna.
1859. July 27	12	Athens, for 28° arc.

The following remarks on the hypothesis that the intensity of the light of the meteors is caused by the oxygen in the atmosphere, are here translated *verbatim* from M. Schmidt's communication to M. Haidinger:—

"In consequence of the observations which were then being made by Benzenberg, Brandes, Felder, Heiss, by myself and others, in the year 1851, I examined into this question more closely, and I arrived at a result which was indirectly opposed to that hypothesis: since it is a difficult matter thoroughly to refute old objections, however untenable, I may perhaps be permitted here to refer to them, and to refer to numbers instead of to opinions.

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* Mr. Greg found one account of this meteor stating it was 20″, seen in an arc of 75°.

"We all know that the intensity of the light of shooting-stars is estimated according to the brightness of the stars, and we therefore, *e. g.*, say that a meteor is of the first magnitude when its light equals that of Arcturus or Vega. If it shines brighter than Jupiter or Venus, we designate it a small fireball. If we put such numerical values for the shooting-stars so as to express the intensity of their light, and if we call h the mean height of the shining portion of the luminous track above the surface of the earth, we obtain the following mean proportional values, which, in the year 1851, I deduced from the observations then made (see my work, p. 111):—

Meteor of 1st magnitude, h=16·2 geographical miles, for 14 observations.
Meteor of 2nd magnitude, h=15·9 geographical miles, for 20 observations.
Meteor of 3rd magnitude, h=10·8 geographical miles, for 24 observations.
Meteor of 4th magnitude, h= 8·5 geographical miles, for 21 observations.

Hence, therefore, it follows that the large meteors belong to the highest regions of the earth, where, as we generally suppose, there exists scarcely any air at all; that, however, the small meteors which have a feeble light are seen nearest to the earth, and occupy the limits of the atmosphere, where the latter still exists in a greater and more perceptible degree, and that they descend still lower. It is therefore *not the oxygen* of the air which is in the main the chief cause and origin of the burning or glowing of the meteors."

Note by Mr. Greg.—That the smaller shooting-stars are frequently nearer than the larger meteors, may possibly be still further supposed to be true, from the fact that usually they are seen to move more rapidly than the larger ones. Still exceptions may exist, as in the case of very large, and probably aërolitic fireballs moving horizontally and parallel to the horizon.

The height at which meteors are not merely luminous, but can leave nearly stationary trains of light, is truly surprising; one would almost have imagined, at that distance from the surface of the earth, some retardation in space of the attenuated and upper stratum of air, as compared with the rapid movement of the earth on its own axis.

It is to be regretted that the extreme limits of the *auroral* regions are not yet more precisely ascertained; but it is not improbable that shooting-stars are commonly visible, or luminous, precisely in that very region, and that their luminosity may to some extent be owing to electrical excitation.

No. 4.—In the 'Comptes Rendus,' vol. xxxvii. p. 547, M. Coulvier-Gravier gives a list of 168 bolides observed from 1841 to 1853, classed as follows:—

1st size	31
2nd size	39
3rd size	98
	168

of which latter, viz. those of the 3rd size, he states as being larger or brighter than Jupiter or Sirius; the relative or absolute size of the two other classes are not stated. These three classes described average arcs or paths as follows:—

(1) 31 ... arc of 42° 4′
(2) 39 ... arc of 26° 7′
(3) 98 ... arc of 22° 7

Their directions at different hours of the night, and numbers, are given in the annexed Table:—

Directions.	6 P.M. to 10 P.M. Number.	10 P.M. to 2 A.M. Number.	2 A.M. to 6 A.M. Number.	Totals.
N.	2	2	...	4
N.N.E.	2	...	2	4
N.E.	3	4	1	8
E.N.E.	1	5	2	8
E.	1	7	2	10
E.S.E.	8	8	1	17
S.E.	4	8	1	13
S.S.E.	4	9	3	16
S.	4	...	3	7
S.S.W.	1	4	5	10
S.W.	...	8	5	13
W.S.W.	3	5	1	9
W.	1	3	2	6
W.N.W.	6	9	8	23
N.W.	4	4	6	14
N.N.W.	...	...	6	6
	44	76	48	168

The 44 bolides which were observed from 6 P.M. till 10 P.M., were seen during 694½ hours of observation, which gives one bolide for 15 hours 47 minutes for that part of the night, of which the average is 9 o'clock.

The 76 bolides from 10 P.M. till 2 A.M. were seen in 848¾ hours of observation, which gives one bolide for every 11 hours and 10 minutes for the second part of the night, with the mean of midnight.

The 48 bolides from 2 A.M. till 6 A.M. were observed in 340 hours, which gives one bolide for every 7 hours and 5 minutes for the third part of the night, the mean being 3 A.M.

The number of bolides being therefore inverse of the times as above, for each bolide, if one allows 100 for midnight, we should find from

	No. of bolides.
6 to 10, average 9 P.M.	= 71
10 to 2, average midnight ...	=100
2 to 6, average 3 A.M.	=158

The number of bolides seen about 6 A.M. is triple the number of bolides observed in the evening, a result which accords with the *horary* and usual variations of shooting-stars generally.

Out of 168 bolides observed, there were 101 which left longer and shorter trains of light of different degrees of duration.

Out of the same number there were 20 which burst into sparks after a course more or less arrested by the rupture.

Lastly, there were 8 which changed their original velocity, or became stationary in their course; two which changed their direction towards the end of their path, and *one* which had an oscillatory movement.

M. Coulvier-Gravier elsewhere remarks that 6th magnitude falling stars have arcs or paths of from 40° to 9°.

In the 'Comptes Rendus,' vol. xlv. for 1857, p. 257, M. Coulvier-Gravier remarks, in a series of observations on the August periodical meteors during a period of twelve years, that the maximum number per hour, from 9 P.M. to 10 P.M., are seen between the N.E. and E.N.E. to 2° 5′ of N.E. From 2 to 3 A.M., between E.S.E. and S.E., 3° of E.S.E. From 9 P.M. to 3 A.M. the maximum has advanced 65° towards the South (or 11° per hour); so that one would conclude that at 6 A.M. the maximum would be between the S. and S.S.E., 7° of S.S.E.

The above is also confirmed by the general result for other months of the year, *i. e.* the maximum for August being in the morning between the S. and S.S.E., the general average for the year, of shooting-stars, being E.S.E.

Mr. G. C. Bompas's valuable generalizations on this fact of the number of meteors increasing regularly from 6 P.M. to 6 A.M., as that the number appearing in the East is double the number originating in the West, are given in a *résumé* at p. 131 of the volume of the British Association Reports for 1857, held at Dublin.

No. 5.—Mr. R. P. Greg gives the following results, taken from a catalogue he has constructed of the most remarkable meteors on record, as regards their general observed direction; without reference, however, to the precise hours of observation, a matter probably of less consequence in very large meteors moving near the earth's surface, than in the case of ordinary sporadic shooting-stars.

Month.	No. of observations.	General direction.
January	17	N.W. to S.E.
February	20	?
March	13	S.E. to N.W.
April	21	N. to S.
May	15	E. to W.
June	18	?
July	14	S.E. to N.W.
August	24	?
September......	22	N.W. to S.E.
October	19	W. to E.
November	39	N.E. to S.W.
December	15	N. to S.

The number for each month here varies quite accidentally, as details concerning precise direction are frequently wanting in the various published accounts of these phenomena.

6. "Observations on Luminous Meteors." By R. P. Greg.

TABLE I.

Catalogue authority.	Number of Bolides and Aërolites, &c. for each month.													
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Totals.	Monthly average.
E. Biot. Analysis of 1354 distinct Chinese meteor observations, from A.D. 960 to A.D. 1275, inclusive of about fifty meteoric showers, aërolites and detonating meteors (Comptes Rendus, xiii. p. 204). ……	65	54	72	65	88	97	185	155	125	208	155	85	1354	113
List of remarkable meteors and bolides; from Arago's 'Popular Astronomy,' translation by Smythe and Grant, vol. ii. p. 500 ………	55	57	48	52	50	43	74	123	64	77	90	80	813	68
Dr. Baumhauer's analysis of his catalogue of bolides and aërolites, from 584 A.D. to 1845 A.D., of which 189 are stated to be aërolitic (Poggendorff's 'Annalen,' vol. lxvi. p. 477)………………………………	69	38	62	54	53	37	63	83	61	69	87	72	765	64
G. Boguslawski's Catalogue, 1854 (Poggendorff's 'Annalen')…………………… Bolides……	85	88	84	83	70	50	82	130	82	93	171	104	1122	93·5
Aërolites …	15	15	23	17	25	22	26	24	17	19	26	16	245	20
Totals ………	100	103	107	100	95	72	108	154	99	112	197	120	1367	113·5

R. P. Greg. Analysis of MS. Catalogue of bolides and aërolites, from A.D. 584 to A.D. 1860, exclusive of Chinese observations*.														
a. Iron and stone falls	10	16	18	15	23	21	20	17	17	18	17	12	204	17·0
b. Detonating meteors	8	8	14	6	5	10	13	8	11	13	17	10	123	10·3
a or *b.* Uncertain which, from Dr. Baumhauer's Catalogue	3	2	6	2	1	2	3	4	3	1	2	4	33	2·7
Total aërolitic	21	26	38	23	29	33	36	29	31	32	36	26	360	30·0
Simple bolides	95	72	72	71	72	58	93	148	104	108	149	111	1153	96·0
Grand total	116	98	110	94	101	91	129	177	135	140	185	137	1513	126·0
Number of principal displays of shooting-stars recorded for each month (Arago)	10	10	12	17	4	2	14	56	13	29	27	17	218	18
Number of auroral displays from A.D. 1800 to A.D. 1830 (Quetelet)	26	12	9	10	5	...	2	10	21	34	25	27	181	15

Analysis of Table I. Mr. Greg's Catalogue.

Description.	First six months.	Second six months.	Six months, winter.	Six months, summer.	December and January.	June and July.
Aërolites (stone or iron falls)	103	101	91	113	22	41
Aërolites, and detonating meteors	170	190	179	181	47	69
Bolides, or fireballs	440	713	607	546	206	151

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* Collated from—Comptes Rendus; Annales de Chimie et de Physique; Nicholson's Journal of Philosophy; London Philosophical Magazine; Silliman's American Journal; Poggendorff's Annalen; Thomson's Meteorology, 1849; Catalogues of the Meteorites in the Vienna, Shepard and Reichenbach Collections; Chladni's Catalogue of Meteorites; Annual Register; British Association Reports; Catalogues of Schmidt, Quetelet, and Baumhauer; Arago's Popular Astronomy, and Boguslawski's Catalogue, being the tenth Supplement to Chladni's Catalogue, in the Supplemental volume of Poggendorff's Annalen for 1854; Rudolf Wolf's Calalogue in der Naturforschenden Gesellschaft in Zurich, 1856; also various periodicals and private notices.

Table II.—Days of the Month on which Bolides or Aërolites have been observed and recorded.—R. P. Greg.

Aërolitic falls and detonating meteors.												Day.	Bolides only.											
Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.		Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
...	...	1	3	1	...	...	...	4	4	...	...	1.	3	4	6	3	2	3	1	4	5	4	3	3
1	...	...	...	...	...	...	1	...	1	...	...	2.	11	1	2	2	6	3	2	3	7	3	6	5
...	2	1	...	...	4	3	...	1	1	...	1	3.	1	4	3	2	1	1	2	10	2	5	5	3
2	...	...	...	1	2	3	2	3	1	...	...	4.	1	3	...	5	3	1	2	2	4	4	6	2
...	...	...	4	1	1	1	2	2½	2	3	3	5.	...	2	1	...	...	1	2	5	4	1	3	4
...	1	2	...	...	2	1½	2	1	1	1	...	6.	3	6	4	4	1	2	3	3	2	5	4	1
...	...	1	...	...	2	2	3	1	...	1	...	7.	2	5	1	...	4	2	...	6	6	4	4	3
1½	1	2½	½	2	...	2	...	...	1	...	1	8.	2	3	5	3	1	1	2	6	4	3	8	9
4	2	...	1	2	1	...	...	1	1	2	1	9.	2	2	2	2	2	4	1	10	1	2	8	5
2	3	1	1	1	1	...	2	2	1	...	1	10.	3	2	3	3	3	2	2	14	7	4	3	2
...	1	1	1	1	1	...	3	1	...	2	2	11.	4	4	1	6	3	...	6	7	3	2	8	10
1	...	3	...	...	4	1	...	...	1	3	...	12.	4	2	1	3	2	3	6	11	1	1	6	4
1	...	1	1	2	1	2	1	3	3	3½	3	13.	5	2	2	3	2	3	4	5	3	6	12	6
...	...	1	...	1	...	1	...	2	1	...	1	14.	1	2	1	3	1	2	3	3	1	5	7	3
1	3	1	3	...	1	2	2½	1	...	1	1	15.	3	1	4	2	4	1	1	6	2	3	6	3
2	...	3	...	...	2	2	...	1	...	...	...	16.	2	...	1	2	3	2	1	4	2	3	6	5
...	...	3	1	3	...	3	...	...	...	1	½	17.	1	2	2	3	1	4	5	2	1	5	4	1
1	3	1	1	1	...	2½	2	...	1	1	...	18.	3	4	3	5	5	1	2	3	2	5	4	4
...	2	3	1	4	...	...	...	2	1	2	1	19.	3	3	2	5	2	3	2	3	2	2	9	2
½	1	...	...	1	2	1	2	...	1	1	...	20.	4	1	4	...	3	2	5	5	5	3	5	2
...	1	3	...	1	1	1	...	...	1	1	1	21.	5	3	1	1	1	2	3	1	1	1	1	9
...	...	2½	...	1	2	1	...	1	1	...	...	22.	2	4	1	...	3	4	2	5	6	4	3	2
½	1	1	...	...	...	...	...	1	1	1	...	23.	3	3	2	...	2	3	5	4	1	5	3	1
...	...	1	...	...	1	...	...	...	...	2	1½	24.	4	1	2	1	3	1	4	...	3	8	1	2
...	1	2	...	...	1	...	...	½	1	1	1	25.	2	1	...	1	...	...	1	5	2	2	2	2
...	...	...	2	2	...	3	...	1	...	...	...	26.	4	2	3	1	3	1	1	5	...	3	3	...
...	2	...	1	1	...	...	...	...	1	1	1	27.	3	2	...	2	2	...	3	1	1	3	4	2
1	1	1	1	1	...	1	...	...	1	2	1	28.	4	1	4	3	...	2	2	4	4	3	3	3
...	...	1	1	...	1	...	...	...	...	2½	...	29.	3	1	4	2	3	2	8	3	2	4	6	4
...	...	2	...	...	1	...	1	...	1	2	...	30.	4	...	3	4	1	1	6	3	4	2	3	5
...	...	2	...	...	...	...	...	...	1	...	...	31.	2	...	3	...	3	...	4	2	1	2	...	1
2½	½	...	½	2	2	3	5½	2	3	2	5	? ?	1	2	3	...	2	1	2	3	3	1	2	3
21	25½	38	23	29	33	36	29	31	32	36	26	Totals.	95	72	72	71	72	58	93	148	104	108	149	111

Analysis of TABLE II.

Aërolitic epochs common to meteor epochs?	Aërolitic epochs probably distinct from meteor epochs.	Times of fewest aërolites.	Times of fewest bolides.
6—10 February?	8—10 January.	Jan. 18—Feb. 6.	February ...24—31.
11—22 July.	14—22 March.	April ......20—25.	April ......19—26.
4— 7 August.	5 April.	April 29—May 7.	June ...... 3— 8.
1— 6 September.	17—21 May.	August ...21—31.	June ......24—30.
1— 5 October?	3—16 June.	September 17—30.	July ...... 1—10.
9—13 November.	3— 8 July.	Dec. 16—Jan. 7.	September 12—19.
27—30 November.			
11—15 December.			

Observations on the preceding Tables, &c.

1. While the number of bolides is considerably larger for December and January than for June and July, the number of aërolitic falls is about as large again for the latter as for the former period; the earth in her orbit in the first case being at her perihelion, in the latter at her aphelion.

2. The distribution of the larger class of meteors is not so unequal throughout the year, if we make allowance for the immense number usually periodically observed in August and November, when meteors as large in apparent size as Jupiter, or even Venus, are not uncommon. March, May, June, and July furnish out of the total number generally observed of meteors of all sizes, the largest proportion of bolides, and especially of aërolites.

3. There is a remarkable equality in the numbers of aërolitic falls for the first half of the year as compared with the second half, viz. 103 and 101 respectively. There does not appear to be any very remarkable preponderance in this class of meteoric phenomena during the periodic epochs for shooting-stars, *i.e.* about the 9th of August and 10th of November. In the analysis of Table II. these epochs are more fully pointed out. There appear to be aërolitic epochs entirely distinct in themselves; and it is worthy of remark that these epochs are apparently most distinctly marked, with regard to shooting-stars and bolides only, during the first six months of the year; whilst all the epochs possibly common to both classes are seen to occur in the second six months of the year, with the single exception of one in February.

4. Analyses of several catalogues are concisely given in Table I. for the purpose of convenient comparison. They vary more or less from each other, though not very materially; necessarily in constructing such catalogues, some latitude and difference of opinion may exist respecting what constitutes a proper *bolide*; and recorded observations may not always be very definite. If meteors of the size of Venus or Jupiter were included without discrimination, the list of fireballs for August and November might be swelled out indefinitely; *e. g.* hundreds of meteors of that size were seen on one night alone, November 13, 1833, in America. The practice of late years of looking out more particularly for shooting-stars at the usual August and November periods, probably tends to increase disproportionately in all catalogues of *bolides*, the number of observations for those two months, though the November period appears for the present to have become very much less remarkable for meteoric displays than formerly.

In constructing his own catalogue, Mr. Greg has endeavoured merely to insert such observations as might with most certainty be assumed to be remarkable for size and brilliancy.

The catalogue itself may possibly appear in a future volume of the Reports of the British Association.

An attempt has been made to separate (as aërolitic) the class of detonating meteors, of which more than 100 are separately given; great care having been taken to obtain the fullest and most accurate list of that class of meteoric phenomena, as being most interesting and most important, but which has hitherto either been statistically too much neglected, or not sufficiently separated and distinguished from the class of fireballs without detonation; large fireballs being frequently said to *explode* or *burst*, though when so expressed only, it must be construed as without noise. It has likewise been the custom with some writers and observers to rank as aërolitic, all the larger class of fireballs, whether observed to burst with or without detonation. Probably *one-third* of the larger fireballs, *i. e.* having an apparent diameter of 15′ and upwards, burst with an audible explosion, this for those observed at night; of those similarly observed during daytime the proportion (according to Mr. Greg's calculations) is greater, probably about *one-half*. It is a singular fact, that out of 72 stonefalls, whose precise hour of fall has been recorded, only 13 occurred before noon, and no less than 58 fell between noon and 9 P.M. Why so few should have fallen at night and before noon, in the morning, it is not easy to say, supposing it not to be the result of chance. If true that more aërolitic falls occur during daytime than during the night, it would seem that there is a greater tendency to encounter those bodies in their orbits, as they recede from the sun; that side of the earth most directly opposite to the sun being naturally most likely to come into actual contact with them. The above observations are taken for average of latitude, say 48° north, and 10° west longitude.

Dr. D. P. Thomson, in his 'Introduction to Meteorology,' p. 302, states that meteors are of comparative rare occurrence in the Arctic Regions: this, if true, is curious and important, and deserves corroboration from some of the great arctic navigators now living in this country, and to whom application for any additional information might readily be made; the long winter nights in those parts being admirably adapted for observations (especially *horary*) of shooting-stars.

The time of maximum meteor visibility being stated by M. Coulvier-Gravier and M. Bompas to be about 6 A.M., it is rather singular that the times of maximum occurrence for aërolites and detonating meteors should be about the same hour P.M.

5. Of the Chinese observations given by Biot, 900 were made in a period of only 79 years, viz. from A.D. 1023—1102; they include meteors of every apparent size from Jupiter to the Moon; likewise a certain number of aërolites, detonating meteors, meteoric showers, and doubtless some few auroral displays. The larger proportion were observed in that portion of the sky included between the S.W. and S.E.

M. Abel Rémusat, in 1819, has published other particulars, viz. of 100 falls of stones and detonating meteors, which have been recorded likewise in Chinese annals, between the sixth century B.C. to 1223 A.D. In Biot's list the 23rd of October presented the maximum number of observations.

6. Further observations are to be desired respecting the zodiacal light, and every possible connexion between that phenomenon and that of shooting-stars or meteors. Likewise further information concerning the heights at which meteors begin to be visible, and cease being visible. The question concerning the cause of luminosity in meteors is a highly interesting one, and still an open one. The phenomena displayed by the luminous trains or tails of shooting-stars and meteors is also a subject requiring much attention. The

theory that they shine by reflected solar light, has been refuted by Mr. R. P. Greg in the April Number of the Philosophical Magazine.

7. It is desirable to distinguish, if possible, between ordinary shooting-stars and aërolites; Olmsted, Dr. Lawrence Smith, and Mr. Greg are strongly of opinion that a distinction may frequently exist, both orbital and physical.

8. In a paper by Prof. W. Thomson in the 'Philosophical Magazine' for December 1854, "On the Mechanical Energies of the Solar System," is developed more fully the idea of Mr. Waterston, that the solar heat can only be maintained, on any known principle, by immense numbers of meteorites constantly striking the surface or atmosphere of the sun, and thus producing by their enormous velocity and friction a never-failing source of heat. The chief objection to this theory arises from the fact that, as far as we practically know anything of meteors, so far from the probability of their being swallowed up in the sun goes, we see the majority of them apparently recurring without waste at periodical times, and that for a long term of years: this simple circumstance goes much against the probability of Mr. Waterston's and Prof Thomson's theory.

Considering that the sun's heat, as an effect of its light, must have been maintained for millions of years (as proved geologically) pretty much at its present value, it is not improbable that future calculations, and a more accurate knowledge of the phenomena exhibited by solar light, may enable us to reduce considerably the supposed absolute heat of the sun, as now measured by an imaginary thermometer, and thus spare us the necessity of supposing that its heat is so great as to require myriads of meteors to be always rushing into it to create a fresh supply of it. If the majority of meteors should be, as they probably are, merely minute and gaseous comets, not possessing a solid or stony nature, it would still more increase the chances against Mr. Waterston's theory.

9. M. Haidinger has recently published at Vienna some valuable papers on the crust and external forms of meteoric stones, in relation to the circumstances accompanying their fall and probable condition prior to, or at the moment of, entering the earth's atmosphere.

Report of the Committee appointed to dredge Dublin Bay. By J. R. KINAHAN, *M.D., F.L.S., Professor of Zoology, Government School of Science applied to Mining and the Arts.*

DURING the autumn and winter months (1859) the author made several excursions to the bays to the north of Dublin, the results of which will be embodied in the final Report. In the spring of 1860, finding that, owing to circumstances beyond their control, there was no prospect of systematic assistance from the other members of the Committee, the author determined to fix on a district to be worked systematically, and selected the series of bays between the Poolbeg Lighthouse and Bray as being the most likely to yield a good return as regards number of species and variety of grounds. Accordingly, since the beginning of March, a series of systematic dredgings have been carried out in this district, the results of which are now communicated. The district may be conveniently divided into three sub-districts:—1st. That between the Lighthouse wall and Kingstown east pier, including Kingstown Harbour. 2nd. The district between Kingstown east pier and the south end of Dalkey Sound, including the whole sound. 3rd. The bay between the latter point and Bray Head, in each case including the banks for seven miles off shore.

Of these the following call for notice:—

Bank 1.—The North Scallop bed lying about three miles off in district I. It consists of pure sand. *Ophiuridæ* are very common; *Ophiocomidæ* not uncommon; *Comatulidæ* scarce; *Asteriadæ* not uncommon: one specimen of *Asterias rosea*, Müller (*Cribella rosea*, Forbes), occurred here. Other Echinoderms rare; Molluscs are rare; Polyzoa and Tunicata are very common; Crustacea, Decapoda, not uncommon, species few; Amphipoda rare; Cirrhipeda common; Annelida are scarce; and Polypifera very common. It may be generally noted, however, as unprofitable ground.

2. Within this a bank of Pleistocene fine sand of considerable extent, but generally narrow in width: this contains very few living shells, but myriads of dead shells, from which all their organic constituents have been absorbed, and which are easily distinguished from the shells found in the next.

3. The Shell Bank.—This, which I have only partially succeeded in tracing out, is a curious belt of broken and living shells, the dead shells being easily distinguished from those of the Pleistocene (Teleocene) beds. Many species of Crustacea are here found; Zoophytes are abundant in certain parts of it; Echinodermata are also common, chiefly *Ophiocomidæ*. *Echinidæ*, *Sipunculidæ*, and *Holothuriadæ* occur more rarely, at least to the dredge, as the oval tentacles of the latter are frequently brought up. This bank is most interesting, as it bears a close resemblance to the Turbot Bank of the Belfast Dredging Committee, many of the shells being identical; and one remarkable coral, as yet only found in the north seas of Ireland, has been detected in it by Mr. E. Waller (*Sphenotrochus Wrightii*). I have traced it nearly the whole way across districts 2 and 3, though in some parts its breadth is narrowed to a few yards; and it bears a constant relation to Bank 2, which in district 3 is called the "Back."

4. Shanganagh Bank, a shingly, muddy, sand oyster-bed, formed from the influx of the river of the same name lying inside the Back in Killiney Bay.—Here *Eupagurus lævis* first occurred to me; *Asterias rosea*, two specimens: *Holothuriadæ* are not uncommon; Zoophytes and Polyzoa not uncommon. Of Mollusca some rare species occur here.

5. Sorrento Bay.—This consists of dense gravelly sand. Here living Molluscs are rare; *Nucula radiata* occurs in some number, and very fine; and Annelids are not uncommon; Crustacea, except *Hyadæ*, are rare.

6. Dalkey Sound.—This district requires almost a special description for itself, though not half a mile long, and barely a quarter of a mile broad, and the depth of water in no place, according to the Chart, exceeding at lowest spring tides 12 fathoms; yet species of every group are met with in it, which are ordinarily reputed to be deep-sea species. I have taken in it, and in it only, *Ophidion imberbe*, *Pirimela denticulata*, *Hyas coarctatus*, *Inachus dorynchus*, *Ebalia Pennantii*, and many other species which elsewhere have only occurred to me in 20-fathom water. In fact, the only species wanting here are those for which I would propose the name of *broad* sea species, such as *Spatangus purpureus*, *Eupagurus lævis*, *Inachus Dorsettensis*, and *Crangon Allmanni*, none of which have ever occurred plentifully except outside the "Back." I defer a full description of this district until my final report, which I hope to present to the Association at their next meeting.

7. The Cnook, a bank about seven miles from land in an easterly direction.—This consists of fine sand and large shells: Zoophytes are very common; Oysters and Scollops also abound. Here I met several species of

Crustacea, which are rare elsewhere,—*Eupagurus lævis, Inachus Dorsettensis, Pinnotheres pisum, Tetromatus Bellianus*, &c. The bank is not easy of attainment, as it requires smooth water for its proper working, and the past season in Dublin has been a succession of easterly and westerly gales.

From all these grounds a number of species have been obtained; of these, the Annelida and Zoophytes are yet undetermined, but the author hopes to put in a list of them at the next meeting of the Association. Of other groups, the following number of species have been determined:—Fishes, 10, one, *Ophidion imberbe*, new to Ireland: Mollusca, 188, exclusive of Polyzoa; of these none are new to Ireland: Crustacea, 75; of these 5 are hitherto unrecorded in Ireland, 8 new to the east coast: Arachnida, 2: Echinodermata, 30, one, *Asterias rosea*, new to Dublin, &c. Sponges are omitted for the present. In the present immature condition of these researches, it were premature to attempt any general conclusions; but the results as yet obtained go strongly to confirm an opinion advanced by the author some years since, regarding the absence of southern types on the Dublin coast, which occur further north, and which led him to the adoption of an eastern Irish or Dublin district, extending from Dundrum Bay to Carnsole Point. For the identification of most of the species the writer is responsible, with the exception of the minute Molluscs; these Edward Waller, Esq., kindly took in hand—frequent recurrence of his initials in the accompanying list will show with what success. Great quantities of the fine sand obtained in these researches is yet unworked, so that it is probable that ere our next report other species may be added to those here given.

To complete the work, the Committee would ask that the Committee may be appointed, with the addition of Edward Waller, Esq., as follows:—Professor J. R. Kinahan, Dublin; Dr. W. Carte; Professor J. Reay Greene; Dr. E. P. Wright, and Edward Waller, Esq.; and that a further sum, not exceeding £15, be placed at their disposal for this purpose, to enable them to COMPLETE this investigation.

List of Species obtained in Kingstown and Killiney Bays, and a few from Baldoyle.

Saxicava rugosa, living, very common.
—— arctica, living, not uncommon.
Sphænia Binghami, living, one specimen: Dalkey Sound.
Mya truncata, dead, not uncommon.
—— arenaria, living, young specimens.
Corbula nucleus, living, not common; dead valves, very common.
Lyonsia Norvegica, living, rare.
Thracia phaseolina, living, rare, double valves.
—— villosiuscula, not rare.
—— distorta, living, rare.
Cochlodesma prætenue, dead, single valves only.
Solen marginatus, dead, single valves only.
—— siliqua, living, in Killiney Bay.
—— ensis, living, in Killiney Bay.
—— pellucidus, living, in some numbers, in Killiney Bay.
Solecurtus candidus, single valves without epidermis: Shell Bank.
—— coarctatus, a pair of valves: Dalkey Sound.
Psammobia Ferroensis, single valves, not common.
—— tellinella, very common.
Tellina crassa, very common.
—— incarnata, dead, single valves only.
—— tenuis, living, rare.
—— fabula, dead, single valves.
—— solidula, rare, living.
—— donacina.
—— pygmæa, very rare, living.
Syndosmya alba, common.
Scrobicularia piperata, one dead specimen, on Shell Bank.
Mactra solida, rare, living here.
—— subtruncata, one single valve.
—— elliptica, very common.
—— stultorum, rare here.
Lutraria elliptica, dead, shells only.
Tapes decussata, uncommon.
—— pullastra, not uncommon.
—— virginea, very common.
Venus casina, uncommon.
—— striatula, rare here.
—— fasciata, common.

Venus ovata, common.
Artemis exoleta, common.
—— lincta, not uncommon.
Lucinopsis undata, rare.
Cyprina Islandica, common, dead; not common, living here.
Circe minima, E. W., very rare.
Astarte sulcata, uncommon.
—— triangularis, E. W., not uncommon.
Cardium echinatum, not uncommon, dead; living small, rare.
—— edule, rare here.
—— pygmæum, uncommon.
—— Norvegicum, not uncommon.
—— nodosum, very common.
—— fasciatum, common.
Lucina borealis, common.
—— flexuosa, Killiney Bay, rare.
—— spinifera, one single valve.
Montacuta bidentata, E. W.
—— substriata, on Spat. purpureus.
Kellia suborbicularis, rare.
—— rubra, E. W.
Lepton nitidum, E. W.
—— squamosum, single valves, rare.
Mytilus edulis, common.
Modiola Modiolus, common.
Crenella discors, common.
—— marmorata, uncommon.
Nucula nucleus, very common.
—— nitida, common.
—— radiata, not uncommon, but local.
Leda caudata, rare, living.
Pectunculus glycimeris, living, rare and small; dead, large and uncommon.
Lima Loscombii, rare.
Pecten varius, rare.
—— pusio, rare.
—— tigrinus, not rare.
—— maximus, not rare.
—— opercularis, very common.
Ostrea edulis, very common.
Anomia ephippium.
—— patelliformis.
—— striata.
Chiton fascicularis, rare.
—— marmoreus, rare.
—— asellus, very common; other species yet undetermined.
Patella vulgata.
—— pellucida.
—— athletica.
Acmæa virginea, common; Dalkey Sound.
—— testudinalis.
Dentalium entalis, uncommon.
—— tarentinum, dead, only fragments, rare.
Pileopsis Hungaricus, rare here.
Fissurella reticulata, uncommon.
Emarginula reticulata, uncommon.
Trochus zizyphinus.
—— granulatus.
—— Montagui.
—— tumidus.
—— umbilicatus.
—— cinerarius.
—— millegranus.
Trochus magus, broken.
—— helicinus.
—— pusillus, E. W.
Phasianella pullus.
Adeorbis subcarinata.
Littorina littorea.
—— rudis.
—— littoralis.
Lacuna vincta.
—— crassior, Shanganagh.
Rissoa Beanii, E. W., one fragment.
—— ulvæ.
—— costata.
—— parva.
—— labiosa.
—— punctura, E. W.
—— inconspicua, E. W.
—— semistriata, E. W.
—— soluta, one specimen.
—— vitrea.
—— striata.
—— striatula, E. W.
Skenea divisa, E. W.
—— planorbis.
Turritella communis.
Cæcum glabrum, E. W.
Aporrhais pes-pelecani.
Cerithium.
—— adversum, E. W.
Scalaria Turtonis, broken.
—— communis.
Eulima polita, E. W.
—— distorta, E. W.
—— bilineata, E. W.
Chemnitzia fulvocincta: Shell Bank.
—— elegantissima, E. W.
—— indistincta, E. W.
Odostomia eulimoides.
—— insculpta, E. W.
—— interstincta, E. W.
—— spiralis, E. W.
—— decussata.
Natica monilifera.
—— nitida.
—— sordida.
Velutina lævigata.
Murex erinaceus.
Purpura lapillus.
Nassa reticulata.
—— incrassata, rare.
—— pygmæa.
Buccinum undatum.
Fusus antiquus.
—— Islandicus.
—— propinquus.
Trophon Barvicensis.
—— muricatus.
—— clathratus.
Mangelia turricula.
—— rufa.
—— septangularis.
—— linearis.
—— nebula.
—— costata.
Cypræa Europæa.
Cylichna cylindracea.

Cylichna truncata, E. W.
Amphisphyra Hyalina.
Tornatella fasciata.
Akera bullata.
Scaphander lignarius.
Philine aperta.
Aplysia hybrida.
Pleurobranchus membranaceus.
—— plumula.
Eolis papillosa.
Tritonia Hombergii.
Doto coronata.
Pholas dactylus.
—— crispata.
Aplidium fallax.
Botryllus polycyclus.
Ascidia mentula.
—— virginea.
Molgula tubulosa.
Cynthia aggregata.
Eledone cirrhosus.
Rossia macrosoma.
Stenorhynchus phalangium.
Inachus Dorsettensis.
—— dorynchus.
Hyas araneus.
—— coarctatus.
Eurynome aspera.
Cancer pagurus,
Pilumnus hirtellus.
Pirimela denticulata.
Carcinus mænas.
Portunus puber.
—— arcuatus.
—— depurator.
—— holsatus.
—— pusillus.
Pinnotheres pisum.
Ebalia Pennantii.
Atelecyclus heterodon.
Corystes Cassivelaunus.
Pinnotheres pisum.
Eupagurus Streblonyx.
—— Prideauxii.
—— Cuanensis.
—— Ulidianus.
—— Hyndmanni.
—— Thompsonii.
Porcellana longicornis.
—— platycheles.
Galathea squamifera.
—— strigosa.
—— Andrewsii.
—— nexa.
—— dispersa.
Palinurus vulgaris.
Homarus vulgaris.
Crangon vulgaris.
—— fasciatus.
—— sculptus.
—— Allmanni.
—— bispinosus.
Nika edulis.
Hippolyte varians.
—— Cranchii.
—— Thompsonii.
—— pusiola.
—— Yarrellii.
Pandalus annulicornis.
—— leptorhynchus.
Palæmon serratus.
—— squilla.
—— varians.
Athanas nitescens.
Lysianassa longicornis.
Anonyx denticulatus.
Ampelisca typicus.
Urothoe marinus.
—— elegans.
Iphimedia obesa.
—— Eblanæ.
Acanthonotus testudo.
Dexamine spinosa.
Gammarus locusta.
—— fluviatilis.
—— palmatus.
—— Othonis.
—— longimanus.
Amphithoe rubricata.
—— littorina.
Podocerus falcatus.
—— variegatus.
Corophium longicorne.
Chelura terebrans.
Hyperia Galba.
Caprella tuberculata.
Comatula rosacea.
Ophiura texturata.
—— albida.
Ophiocoma neglecta.
—— Ballii.
—— bellis.
—— rosula.
—— minuta.
Uraster glacialis.
—— rubens.
—— violacea.
—— hispida.
Cribella oculata.
—— rosea.
Solaster papposa.
Asterias aurantiaca.
Echinus sphæra.
—— Miliaris.
Echinocyamus pusillus.
Spatangus purpureus.
Amphidotus cordatus.
Cucumaria fusiformis.
—— Hyndmanni.
Thyone papillosa.
Synapta inhærens.
Syrinx Harveii.
—— granulosus.
Sipunculus Bernhardus.
Priapulus caudatus.

Detailed notes on the species will accompany the final Report.

Report on the Excavations in Dura Den.
By the Rev. JOHN ANDERSON, *D.D., F.G.S.*

IN reporting on the operations and researches in Dura Den during the summer of 1860, the Committee laid open several large sections of superincumbent boulder clay and of the underlying yellow sandstone, but were unsuccessful in obtaining any of the *Pamphractean* or *Pterichthyan* forms sought after. None of the workmen engaged in the excavations in 1837, when these organisms were found in great numbers, were living in the district; and the Committee, proceeding on the information of others, failed to detect the precise fossiliferous bed in question. Their labours brought them, however, to a point which cannot be far distant from these crustacean treasures, and they are hopeful that, on resuming their researches, they shall meet with the desired success. They proceeded to other sections of the rock, in the bottom of the ravine, and there they were richly rewarded with an abundance of the fossil remains of fishes, chiefly of the genus *Holoptychius* and other *Cœlacanths*.

The yellow sandstone deposit, as described in the 'Course of Creation' in former papers of Dr. Anderson, consists of an alternating series of grits, shales, marls, and fine-grained sandstone, of various shades of colour. The fossil fishes are confined to one particular bed, which, when laid open, easily splits up, the organic materials determining the point of separation, and exhibiting often on a single flag from fifty to a hundred closely-packed and well-defined figures with scales, fins, and cranial plates quite entire. On the present occasion your Committee were surrounded by an intelligent group of lovers of the science, male and female, from Edinburgh, St. Andrews, Forfar, Dundee, and Cupar, and succeeded, after a few hours' labour, in displaying to their eager gaze some of the largest and most beautiful specimens of these older denizens of our seas.

It will not be necessary to describe in detail any of the well-known forms and characteristics of *Holoptychius*, the most abundant of the genera found in this deposit. But having submitted some of the most perfect of the specimens to Professor Huxley, and as he thereby was enabled to detect some new particulars connected with the structure and figure of the genus, it will not be deemed out of place to give an abstract of his interesting description, contained at length in Dr. Anderson's 'Monograph of Dura Den*.'

"In studying," says Professor Huxley, "the new forms of Devonian fish which have been described, I found it desirable to obtain a more definite conception than was deducible from extant materials, of the characters of *Holoptychius*. To this end I examined a considerable number of specimens of *Holoptychius Andersoni*, contained partly in the collection of the British Museum, partly in that of the Museum of Practical Geology, and I have arrived at the following conclusions. *Holoptychius Andersoni* has very nearly the proportions of a carp, but its body is thicker and its snout is more rounded from side to side. The greatest depth of the body is in front of its middle; the length of the whole body is to that of the head nearly as five to one. The orbit is nearly circular, about one-fourth the length of the head. The cranial bones all exhibit a peculiar granular structure. The two parietals occupy a large extent of the upper wall of the cranium, and have the form of pentagons with their elongated bases turned inwards and applied to one another. The occipital region is covered by three bones, one median, and two lateral; the lateral bones having radiating striæ on the posterior halves of their outer surfaces. The operculum is a broad bone, larger behind, where it is convex, than in front, where it is concave, and much longer than it is deep.

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* Dura Den; A Monograph of the Yellow Sandstone and its remarkable Fossil Remains. By the Rev. J. Anderson, D.D., F.G.S. Edinburgh: Thomas Constable and Co.

"The rami of the lower jaw are stout and strong, and form a very broad, almost semicircular arch. The characters of the scales are well known. The fins are lobate, and the dorsal fin is small and triangular. Sir Philip Egerton, in a valuable memoir recently read before the Geological Society, expresses his belief that *Holoptychius* has two dorsal fins. I am very loath to controvert the opinion of so experienced and skilful an observer, the more particularly as specimens of *Holoptychius* with perfect tails are very rare, but one or two complete examples I have seen, leave no room in my mind for any other conclusion than that stated above."

Numerous perfect specimens of this remarkable fish have been obtained in our recent excavations, which show the lobate character of the fins as described by the learned Professor, as well as the *unity* of the dorsal organ. The entire form of the body of *Holoptychius* is likewise beautifully developed in some of the specimens, where the caudal end appears gradually tapering to a point, and not at all *bent up* as represented in all former descriptions; while the ventral lobe of the caudal fin, though rather shorter than the dorsal lobe, has nearly the same depth, and not in the ordinary sense of the heterocercal structure.

In the course of our explorations we also succeeded in obtaining several perfect specimens of two new and hitherto undescribed genera of Cœlacanths, namely, *Glyptolæmus Kinnairdii* and *Phaneropleuron Andersoni.*

The *specific* distinction of *Glyptolæmus Kinnairdii* was proposed and adopted at the Meeting of the London Geological Society in honour of Lord Kinnaird, whose zeal in promoting the interests of geology is only equalled by his enlightened endeavours to advance the interests of anything connected with our social and industrial well-being as a statesman. The *generic* term of *Glyptolæmus* was suggested on account of the marked sculpture of the jugular plates in one of the specimens. As described in the "Monograph" of Dura Den, the scales and fins likewise form strongly marked characteristics of this new genus.

The scales are rhomboidal, and have an average short diameter of one-sixth of an inch. Twenty-four series are visible, and diverge from the median line in the ordinary way; they are larger on the anterior part of the ventral surface than on the posterior part, and at the side of the body than on the belly. They are pitted and ridged almost as in *Glyptopomus,* although somewhat thinner and less bony than in that fish. There are two dorsal fins which are situated very far back, the anterior edge of the root of the first being nine inches distant from the end of the snout in one of the specimens: it is remarkably slender, and of a semi-oval outline. The second dorsal fin is considerably larger than the first, being two inches on its longest axis, and its breadth about an inch in depth. The entire length of the body, in several of the specimens, varies from a foot and a half to nearly two feet.

The other new genus discovered in the course of our explorations is the *Phaneropleuron Andersoni,* and from some very imperfect fragments named by Professor Agassiz as a *Glypticus,* but without describing or defining the genus. The generic appellation, now bestowed by Professor Huxley, expresses the most striking character of the fish—the curious development and obtrusiveness of its ribs, arising from their complete ossification as well as the thinness of the scales. The affinity of *Phaneropleuron* with the typical cœlacanths is indicated not only by its singular tail, but by its persistent notochord, by its lobate pectoral and ventral fins, and by its well-ossified superior and inferior vertebral elements. The scales remind one of *Holoptychius*, but are much thinner and differently sculptured. The fins are more nearly of the structure of this genus in their general facies, though they differ in details. They are lobate in the lateral pairs, a character now regarded by one of our most eminent ichthyologic authorities, Sir Philip Egerton, as belonging to the entire family of Cœlacanths, and which Agassiz has also described in his elaborate account of the *Glyptolepis* of Clashbennie in the 'Poissons Fossiles.'

This locality, so richly stored with these and other forms of fossil remains, has now contributed largely to our stock of palæontological knowledge. Should the researches be continued, your Committee are sanguine, not only in the recovery of the long-lost bed of the disputed *Pamphractus*, but likewise of new genera and new species still sealed up in the yellow sandstone museum of Dura Den*. Trilobites of a small type, Productæ and Spirifers, are very numerous in the carboniferous shales of Ladeddie, which are in immediate superposition and stretch along the southern opening of the Den. About three miles to the eastward, in the ironstone deposits of Denbræ and Mount Melville, large jaws, teeth, bones, and scales of the genus *Rhizodus* are in the greatest abundance and the most beautiful preservation. Thus the geologist may here study successively the upper beds of the Old Red Sandstone, the Mountain Limestone, Ironstone shales, and the Coal-measures on the most northern limits of the Carboniferous system. Trap-rocks everywhere penetrate the series of sedimentary deposits, indurating the sandstone, fusing the limestone, roasting the coal, and exhibiting proofs of those destructive agencies and deleterious impregnations by which the fishes of Dura Den were suddenly overtaken, silted up, and preserved in such numbers and perfect forms in their stony matrix.

Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester. By JAMES BUCKMAN, *F.L.S., F.S.A., F.G.S. &c., Professor of Botany and Geology, Royal Agricultural College.*

IN presenting our Report for 1860, it will be necessary to remark, that on account of the peculiarities of the season, particularly its lateness, and the fact of the unusual period of the Oxford Meeting, the Report before the Section at Oxford was made verbally, permission having been obtained to make a more full and written report when the experiments had attained to something like completion. It was reported before the Section that 200 plots were in operation, which were classified as follows:—

	Plots.
Agricultural Plants	50
Medicinal Plants	30
Esculent Vegetables	20
Grasses, old and new plots	60
Miscellaneous Plants	40
Total	200

Of these, at the Oxford Meeting it was reported that more than half were either new seeds only just germinated, while for the others they had made so little progress, that we almost despaired of any substantial results under such untoward circumstances. Still, however, we now offer remarks upon some of the more striking experiments, which it may be said are so far complete up to November.

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* See Reports of the British Association for 1858 and 1859.

GRASSES.

Sorghum saccharatum (*Holcus saccharatus*), Chinese Sugar-cane.—The fine summer of 1859 enabled us to grow this plant to a height of as much as 7 feet, as also to perfect its saccharine matter, at least in a very high degree. This success, which was pretty general all over England, had caused very flattering encomiums to be passed on the merits of this plant for agricultural purposes, especially as a green soiling food. The total failure, however, of our experiments for this season is not only instructive as to the great diversity of seasons, but should also teach us caution in recommending the extensive adoption of any new plant in our uncertain climate from only a single year's growth. *Our best plants did not attain* 6 *inches*, and indeed our failure this year was more signal than our success the previous one.

Ægilops ovata.—Although our specimens are far later in coming to maturity than in any former season, yet the results are more striking than we have before observed. Even at the time of our writing (November), little of our crop for 1860 has ripened; but the spikes are longer than usual, whilst the stalks (culms) are taller; and added to this is the important result of a show of more and larger grain, of the shape of the wheat grain, so that we have scarcely a doubt left as to this being the parent of the cereal or corn wheat. Again, as another evidence of the results and effects of cultivation, we have the crop of this year affected with all the epiphytical fungi to which wheat is liable, and the more so the more it is manured.

Gyneria argentea, Pampas Grass.—Our specimens, one of which flowered most beautifully last year, are all dead, so that however highly this plant may be recommended for naturalization in other parts of England, where the climate is milder, we cannot think it will ever be safe to trust to it on the "Stony Cotteswolds."

Of British Grasses, we have to report that we have had in operation during the present season as many as sixty plots; several of these are only our usual common English species, many of which are condemned to be resown on account of their inevitable admixture. Among the experiments of interest, we have to report the complete production of *Festuca elatior* from a plot of *F. loliacea*, in which the changes were as follows:—

2nd year.—*Festuca loliacea* the rule, with exceptional cases of *F. pratensis.*
3rd year.—*Festuca pratensis* the rule, with exceptional cases of *F. elatior.*
4th year.—*F. elatior* increased.
5th year, 1860.—*Festuca elatior* has complete possession.

In reference to this, it will be remembered that we noted in a former Report the occurrence of *F. elatior* in Earl Bathurst's Park, which we then conjectured had been derived from the sowing of the seed of *F. pratensis.* This year we have further to remark that here the *elatior* form is the rule, and scarcely a vestige of the *F. pratensis* remains; and very coarse and unsightly it is as a glade in a park.

We have now performed this experiment twice with the same result, and our views seem confirmed by the accidental case just referred to; we have then no doubt that the three forms just adverted to are but varieties of a single species; and we have much pleasure in observing that our views in this and other cases of a like kind, derived from actual experiment, and reported upon to the Association in 1847, should be confirmed by the

Specific Botanist as thus: under the head of "Meadow Fescue, *Festuca elatior*," see Bentham's 'Handbook of the British Flora,' p. 602, we have the following:—

"a. *Spiked Meadow Fescue* (*F. loliacea*, Eng. Bot. t. 1821). Spikelets almost sessile, in a simple spike. Grows with the common form, always passing gradually into it.

"b. *Common Meadow Fescue* (*F. pratensis*, Eng. Bot. t. 1592). Panicle slightly branched but close. In meadows and pastures.

"c. *Tall Meadow Fescue* (*F. elatior*, Eng. Bot. t. 1593; *F. arundinacea*, Bab. Man.). A taller, often reed-like plant, with broader leaves, the panicle more branched and spreading. On banks of rivers, and in wet places, especially near the sea."

Now, though well aware that these views are not generally shared by collecting botanists, we are yearly more and more persuaded that even greater innovations than now contended for will be admitted; and we cannot help expressing pride and pleasure that we should for the last fourteen years have been conducting a series of experiments, many of which practically prove the truth of several of the theoretical views, with regard to what has been termed the "lumping" of species, of the author of the Handbook; and we cannot here omit expressing our best thanks to the British Association for their assistance in prosecuting these interesting inquiries.

Poa (*Glyceria*) *aquatica*.—Our plot with this experiment still continues to exhibit *in its entire space, without the slightest intermixture*, the induced form we have before reported upon, which indeed is so different from the original grass, that at a first glance most observers would pronounce it to be large examples of *Poa trivialis*; the differences, however, in all parts are as great between our induced form and that grass, as exists on comparing the induced form with the *Poa aquatica*. There can be no doubt that in this case the cultivation of the seed of a water grass in an upland situation has led to great changes, not, as has been supposed, brought about by cross-breeding or hybridizing, but the seed of the *P. aquatica* has at once been changed in the growth of the plants that came up from it; and it now remains to see if the change be a permanent one, to which end we hope to be able to sow a plot of the seed of the induced grass next spring; but in the meantime it may be well to remark, that although it has frequently seeded, yet that the bed is still free both from innovations from seedlings of its own kind, as also from those of other species.

Poa (*Glyceria*) *fluitans*.—At the same time that the plot was sown with the seed of *P. aquatica*, another plot was occupied with seeds of the *Poa fluitans*; and we should remark that in both cases the seeds were drilled, and the drills remain intact to the present hour. Now the result is, that both plots were indistinguishable at the first time of flowering, and have so remained to the present hour; and with reference to the last form, it may be well to point out that, having been favoured by Messrs. Sutton of Reading with specimens of the collection of grasses which they keep in cultivation, a bundle marked "*Glyceria fluitans*" is identical with our induced forms from both *P. aquatica* and *P. fluitans*.

Poa aquatica and *P. fluitans*.—We offer no explanation of these; being well acquainted with these two species, we can truly say that our induced form is widely different; nor is it at all identical with any other British species. It is, however, still a matter of regret that we have not been able to procure ripe seed of these species from the district, as, so far as we can discover, none of the *P. aquatica* at least has ripened in the district. It may be well to mention, that even this shyness in the ripening of the seed of this now so emphatically a water grass, is not without value as affording something like evidence that this species is perhaps after all out of place, and this may point to the fact that our induced form is the right one; at all events, it quite determines the fact that the name *Glyceria* is inapplicable, as it is a decided *Poa* in cultivation.

CROP PLANTS.

Pastinaca sativa, Parsnip.—Our ennobled examples of these were considered so perfect, that it was thought advisable to consign the whole of the seed of 1859 to the Messrs. Sutton of Reading, as new varieties of any cultivated crop plant is always desirable, and more especially when, as in the present case, the new form has been directly derived, not from a variety, but from the original wild stock. In reference to the continued success of this experiment, Mr. Sutton reports in a letter of October 17th of this year as follows:—

"The Student Parsnip in our trial ground is the nicest shape of any, more free from fibres, and as large as the 'hollow crown,' which is a good medium size. The flavour seems to be very nice."

This is the more important, as of late this useful garden esculent has much fallen into disuse, its want of flavour being the assigned cause.

We must not omit to remark, that one of the most malformed specimens of parsnip, and also a highly digitated Swedish Turnip, were set aside for seeding, with a view to sowing next spring in the same kind of plots, as there seems reason to expect that such degenerate forms could only beget a degenerate progeny: with a view then to ascertain how far this degeneracy, or otherwise, may proceed, we first took careful portraits of the seeded roots, the seed of which is now put by for experiment.

Brassica oleracea.—Having gathered some seeds of this wild cabbage from Llandudno, N. Wales, in August 1859, we sowed it in the summer of the present year in our private garden, from whence we removed some plants for a plot in our College garden. These, and our own examples, are already highly curious, as showing the tendency to run into so many of the cabbage varieties, *e. g.* long petioles; the types known as "kale, greens," &c., both with broad, more or less undivided leaves, and with a tendency to deep lobes and divisions. Others with short petioles, offer the true cabbage type; while these even now show tendencies for the production of sorts, as flat heads, sugar-loaf, green, red, and white varieties. These of course are what one would expect, but still it is curious to mark its progress.

In speaking of the *Brassica* family, we cannot help expressing our conviction of the justice of including the genus *Sinapis* with *Brassica*; for just as our experiments incline us to the opinion that all our so-called species of this genus are after all only derivatives, so we believe that the Charlock *Sinapis arvensis*, L. is also an agrarian form of *Brassica.* Upon this, however, we want the experiments of a lifetime; still these would be replete with interest, and more especially as we find cabbage, rape, turnips, radishes, and mustard almost wholly attendant upon cultivation, and that not only with us, but in every variation of climate. How wild the thickets of *Sinapis nigra*, some 6 feet high, look on the banks of the Ohio! and yet we have the authority of Beck in favour of its introduction from Europe; and so we have evidence of the crops in India being smothered with wild rapes, which our experiments show are principally *bulbless* varieties of the turnip.

Mangel Wurzel.—The inquiry connected with the growth of this crop is one which may be considered of interest in a physiological as well as an agricultural point of view, and hence we give its results in this place, It is tolerably well known that this valuable crop was introduced into cultivation with the hope that it would yield a valuable supply of food in the shape of leaves, whilst at the same time it was supposed to be capable of fully developing its growth of roots, the leaves then being employed for summer and autumn food, whilst the roots were to be stored for winter use; however, we were early struck with the fact, that using the leaves to any extent, would prejudice the crop of the roots, and we therefore twice before the last year instituted experiments upon this matter with a result that may be generally stated as follows.

The Mangel Wurzel, stripped of its outer leaves from two to three times during their period of growth, *do not produce half the weight of root of those left intact.*

And herein we thought that we had established the law, that as long as a leaf of Mangel was sufficiently sound to be useful as food for any animal, so long was it of use in aiding the proper development of the plant; but this statement has been controverted by the result of some experiments made at the Albert Agricultural Model Farm, Ireland, where it is stated that the result of taking the enormous quantity of *5 tons of leaves from the acre of a growing Mangel crop, was to increase the weight of roots at the rate of nearly 5½ tons.* Now, under these circumstances we determined upon repeating the experiments upon a larger variety of Mangels this year.

1st. A set of experiments made with nine sorts of Mangel Wurzel planted with burnt ashes, duly thinned and tended as usual; the plots being 2½ yards square.

2nd. Nine plots of the same sorts transplanted.

The outer leaves of all these plots were taken off on the two following dates, September 4 and September 21.

On the 12th of November the whole crops topped and tailed, consisting of twenty-four roots to each bed, half of which had been stripped of their outer leaves; thus twelve roots each, stripped and unstripped, gave the following results for both the untransplanted and the transplanted plots:—

Untransplanted Plots.				Transplanted Plots.	
Names.	Entire.	Stripped.		Entire.	Transplanted.
	lbs. oz.	lbs. oz.		lbs. oz.	lbs. oz.
1. Elvethan	8·10	5· 4	1	14·10	5·10
2. Yellow Globe	9· 0	5· 2	2	13· 0	6·14
3. Red Globe	8· 2	6·12	3	15· 4	7· 3
4. New Olive-shaped Red Globe	11·13	7· 6	4	12· 4	5· 6
5. New Olive-shaped Yellow Globe	16·13	12· 3	5	11·14	7·10
6. Sutton's New Orange Globe	9· 5	3·12	6	10· 2	5· 9
7. Improved Long Yellow	19· 0	9·11	7	15·10	11· 1
8. New Long White	15· 0	7· 8	8	12·11	7· 6
9. Silver Beet	16·15	5· 9	9	15·13	6·11
Total	114·10	63· 3		121· 4	63· 6

Here then we take these results from so many sorts as conclusive evidence upon this point, only remarking that, in all probability, had the season been one of an ordinary kind, the discrepancy would have been even greater, as this year the tendency of growth has been in favour of leaf development.

The same experiments were tried with Kohl Rabbi, and with the like results; and it should be mentioned, with regard to all of them, that the seed was obtained from the Messrs. Sutton of Reading, and that it was true to sort.

It s not a little remarkable that in both the Mangel and Kohl Rabbi the results have been greater in the transplanted than in the untransplanted plots, the former yielding a larger crop; this too has probably been favoured by the moist season, but as it is a subject of great farming interest, we shall renew our experiments upon this matter.

Dipsacus fullonum et *sylvestris*.—Our plot of this year fully confirmed our view of last year, as to the specific identity of these two forms of this plant; for without being able to assert that we had decided *D. fullonum* from the seeds of *D. sylvestris*, or the opposite, yet the specimens glided so imperceptibly into either form, that, distiuct as are decided examples, we were much puzzled in deciding as to the paternity of some of our specimens.

To quote from English Botany, 2nd edition: "Hudson mentions this plant as growing about hedges. In the clothing countries, where it is cultivated for use, it may escape from the fields. There is much doubt concerning the value of its specific difference from the *D. sylvestris*."

Bentham is of the same opinion, so that our experiments in this only lay claim to a simple and practical method of confirming these views. Our notion at the same time is that it would be exceedingly difficult to find a wild example of the true *D. fullonum*; that is, one which from its hard reflexed bracts would be worth anything for fulling purposes. We have hunted long in the districts where the economic form of the Teasel is grown, and we have always been of opinion that where its seed has been scattered and allowed to grow wild, it lost its stiff hooked characters; and, to say the least, even the best of them merged into *D. sylvestris*; the *fullonum* being indeed a difficult plant to keep perfect, unless under constant change of seed and soil.

Weeds, &c.

Thistles have formed the subject of several experiments during the past year, which will be referred to under the following names:—*Carduus arvensis*, *C. acaulis*, vars., *C. tuberosus*.

Carduus arvensis.—Our experiments upon the growth of this plant were undertaken in order to explain their method of reproduction, as it had been disputed by the farmer that thistles were produced from seed.

On September 2nd, 1859, were sown ten seeds which had been collected a few days previously; by the 21st of the month these had all come up, and some began to show the secondary leaves, as in Diagram, fig. 1. By the time the prickly foliage became manifest, the cold weather had set in and all the plants apparently died. However, in February 1860 we noticed a bud just emerging through the soil, which induced us to take up a couple of the specimens and make drawings of them, of which copies will be seen at 2 *a* and 2 *b*.

Here then at *a* and *b* are buds by which the continuance of the plant is secured, the buds *a*, *b* forming whilst *b*, *b* are sending up leaves for the second year, so that by June the plants had advanced to the condition of fig. 3, in which, while a strong shoot is progressing above ground, a most extraordinary rhizomation is taking place below fig. 3, fully explaining how in the next season we may meet with a thicket of Thistles derived from a single plant.

Here then it is obvious that the conclusions with respect to the Thistle not seeding, were the result of the small and inconspicuous plant which it makes the first year, and this *apparently* dying, confirmed this view; however, we see from this experiment that thistle seed is as fecundate as that of other plants, and as we have counted as many as 150 seeds from a single head of flowers, and as we may have an average of ten heads of flowers to a single flowering stem, the eight tertiary buds at fig. 3 *a*, *a* may each represent a flowering head in the following season, which would thus give us the following sum as the seeding capabilities of a single Thistle plant, namely—

$$150 \times 10 \times 8 = 12000.$$

These figures then will account for the "Plague of Thistles" which one sometimes hears of, and points out most forcibly the importance of not allowing these plants to perfect their seed, and hence waste places and neglected waysides should carefully be watched in this respect; but as this cannot adequately be done without compulsory enactments, it is interesting to find that some of our colonies have already instituted state laws with reference to this subject, and during the last Session of Parliament an attempt was made to get an act applicable for this object for Ireland. The destroying of such thickets of Thistles as we have described has ever been an object of interest with the farmer; and it is not a little curious to remark that the operations connected therewith have so much been regulated by rhyming directions, as follows:—

"Thistles cut in April,
Come up in a little while;
If in May,
They grow the next day;
If in June,
They 'll grow again soon;
If in July,
They 'll hardly die;
If in August,
Die they must."

These words, uncouth as they are, are still meant to express some important facts in the natural history of the plant. It may be observed that, with the preparation we have described of underground buds, there can be no wonder at the quick reappearance of the plant on early cutting; at the same time, if we consider that the whole of the aboveground parts of the plants would naturally die at the first approach of cold, we may conclude that the decree of

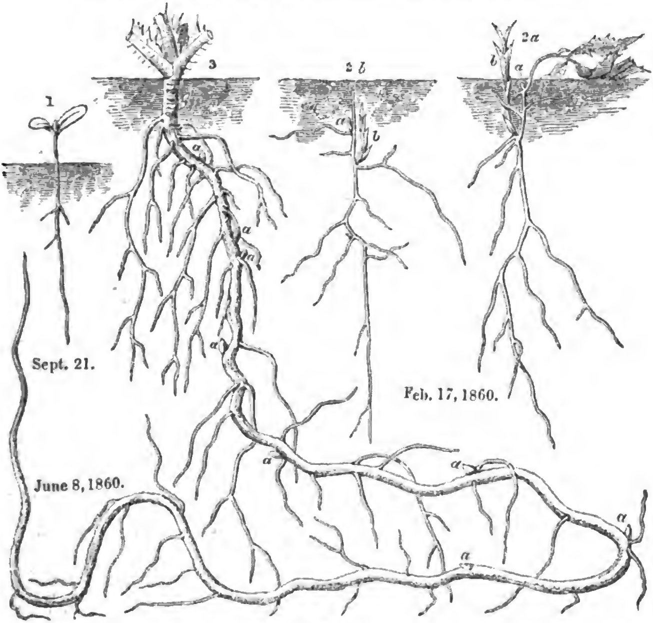
"If cut in August,
Die they must"

is more apparent than real. For while the tertiary buds are advancing to flower, they are also active in providing a still newer growth of rhizomata and buds to perpetuate the continuance of the plant; and hence we have no hesitation in saying that never can this thistle be destroyed by late cutting off its aboveground stems. However, even at this time much good may be done in keeping down the reproduction of the plant; for by the August mowing seeding is prevented, though even for this object we should prefer an earlier cutting, as one head of flowers usually ripens at a time, and not all at once.

Carduus acaulis.—We last year reported upon our experiments with the true acauline form and the slightly cauline examples of this species; we have now to remark that the acauline examples maintain their normal condition, whilst the cauline ones, from being only about 3 inches high when selected for the experiment, have this year advanced to a complete thicket of stems nearly a yard high, some of which have as many as a dozen heads of flowers, and is a very showy and handsome plant.

Carduus tuberosus.—The specimens originally discovered by us at Avebury Druidical Circle have now advanced to immense masses, both as regards their summer development of flowers and their tuberous rootstocks; the flowers are above 3 feet high, much branched and very showy, very different from the single, or at most two-headed flower-stems of the 'English Flora,' pl. 2562, which, however, is a faithful representation of the plant we transported to our garden. The tubers with us are as large as those of Dahlias, We should remark that this year we have a number of seedling plants which have come up wildly in different parts of our experimental garden, which we shall be curious to know if they become like their parents. With us it seeds so enormously, that it can hardly fail to be a matter of interest as to how this plant, originally noticed as from Great Ridge between Boyton House and Fonthill, Wilts, should have been for so many years lost to our flora, whilst its present natural habitat on artificial earthworks, though truly ancient enough, would seem to point to its having been introduced to its present locality.

Diagram showing the mode of Growth of Carduus arvensis.



⅓rd nat. size.

Fig. 1. Seedling of the first year.
Fig. 2. *a* & *b*. The position of the seedling plants in spring sending up secondary buds *b*, *b*.
Fig. 3. The secondary shoot advanced to a large plant, while the rhizome extends and tertiary buds *a*, *a* are prepared for the following year.

Bentham, in his description of the position of this plant, has the following remarks:—

"In moist, rich meadows, and marshy, open woods, in western and south-central Europe, extending eastwards to Transylvania."

Its position at Avebury is so very different from this, that we cannot forbear to describe it. Avebury Circles (of stones) are placed on an elevated plain of chalk, around which are elevated mounds or earthworks, the whole surrounded by a broad deep vallum, which is at all times perfectly dry, and it is on the driest and most exposed part of the mounds that the plant occurs. Its change from such a poor position to our garden, which though only unmanured forest marble-clay, is yet moist and stiff, will doubtless account for its wonderful growth.

Cuscuta epilinum.—Our last year's report on experiments in the growth of this Dodder excited so much attention, that we determined upon following out some additional ones in the present season, to which end we sowed two plots with flax-seed, as follows:—

Plot 1. *Flax-seed perfectly pure.*—The result was a very fine crop, perfectly clean.

Plot 2. *Dirty Flax-seed with some seeds of* Cuscuta epilinum *intermixed.*—This was scarcely half a crop, and the fine specimens of Dodder bearing down the partial crop, is at once an evidence of the mischief this parasite can do to the crop in question, as also of the perfect ease with which we can grow it; so also how easy to prevent its presence in the flax-crop if we take care to sow pure seed.

As regards the Clover Dodder, though this pest is yearly becoming more and more prevalent, yet this season has been especially bad for ripening its seed, and we are still in want of seed for special experiments upon it.

Seeds of *Orobanche minor* have been collected this year with a view to a series of experiments upon it, as the Broomrape, like the Dodder, is yearly becoming more and more troublesome; and it would seem that Clovers are liable to attacks from both forms of the parasite, and in all probability of more than a single species of either; for, as regards Broomrape, we have collected the two forms *O. minor* and *O. elatior* from different Clover crops; we still want to know whether the *Cuscuta europæa* and *C. Trifolii* are specifically distinct.

Myosotis.—We last year reported upon some curious changes wrought in the cultivation of *M. sylvatica*, in which we gave it as an opinion that the *M. palustris* of authors was subject to great variations, giving rise to annual as well as perennial forms, the former introducing us to the *M. sylvatica* and others, as offsprings of *M. palustris*. Our present stock still bears out this view, as we have as derivatives from *M. sylvatica* a still decreasing flowered form and annual and perennial conditions of our varieties.

This year we introduced into the garden the very bright blue Forget-me-not of our ditches; this in cultivation (the same plant) has become the small flowered light blue form which we take to be the *M. repens* of Don, as described by Mr. Babington.

While upon this subject we must not omit to mention that, having been favoured with a packet of seed from the eminent firm of J. Carter and Co. of Holborn, under the name of *Myosotis azurea major*, we were much interested in observing what kind of bedding plant it might make, particularly as in the Seed Catalogue for February 1860 we find the following remarks appended to the *Myosotis* species:—

"Forget-me-not. These beautiful flowers are too well known to need recommendation: will grow around fountains, over damp rockeries, or in any moist situation. *M. azorica* and *azurea major* are the finest."

Of course, from this announcement we expected something rather choice; but our disappointment may be guessed when we found the result to be a very poor small light-coloured variety of *M. palustris.*

Now, we are far from blaming the Messrs. Carter for this, as it will at once be seen that this was an induced form, and no one can at all answer for its permanency; and it may be that our position or some new circumstances of cultivation induced the change from an expected fine flower to a very insignificant one. Still this affords another curious instance of the effects of cultivation upon this genus, which seem to tell us that we must not be too positive in the specific distinctions adopted by authors for these plants.

The effects of the season of 1860 have been remarkable in several particulars; we would, however, only refer to a few plants under experiment.

Dioscorea Batatas, Potato Yam.—Smaller than ever; cannot be at all depended upon, even to make its seed in the Cotteswold district.

The Cabbage tribe sadly cut up with us, but the Brussels Sprout was found to be the most hardy of any kind.

Gyneria argentea.—Killed entirely, both in the College and our own private garden.

Sorghum saccharatum.—Scarcely attained 6 inches in height against 7 feet of the previous year.

Zea Mays.—Indian corn not 2 feet high, and died as soon as flowered.

Roots of all kinds smaller than usual.

Potatoes small in quantity and much diseased.

Fruits have not attained their usual size, have not ripened, and are flavourless.

Forest trees have made little wood, and their new shoots are not ripened.

Garden flowers made little growth, shabby both in leaves and flowers.

Plants perfected for less seed than usual.

Cirencester, November, 1860.

Report of the Committee requested "to report to the Meeting at Oxford as to the Scientific Objects to be sought for by continuing the Balloon Ascents formerly undertaken to great Altitudes." By the Rev. Robert Walker, *M.A., F.R.S., Reader in Experimental Philosophy in the University of Oxford.*

In presenting their Report, the Committee would observe at the outset that the main object for which the former Committee (in 1858) was appointed remains yet unaccomplished; and this is the verification of that remarkable result derived from the observations of Mr. Welsh in his four ascents in 1852, viz. "the sudden arrest of the decrease in the temperature of the atmosphere at an elevation varying on different days, and this to such an extent, that for the space of 2000 or 3000 feet the temperature remains nearly constant or even increases to a small amount." It is obviously important to determine whether this arrest represents the normal condition of the atmosphere at all seasons of the year. The ascents of Mr. Welsh were made between the 17th of August and the 10th of November. The question remains, whether this "arrest" would be observed before the summer solstice as well as after, and whether there were any variations at different seasons. The changes in the temperature of the dew-point, consequent upon this interruption in the law of decrease of temperature, would extend our knowledge of the condition of the atmosphere at such altitudes. To accomplish thus much would not require ascents to very great altitudes, although there are many objects to be attained by ascending as high as possible. The liberal offers that have been made by Mr. Coxwell and Mr. Langley, of Newcastle, would enable observations to be made at a very moderate cost, and Mr. Langley appears fully competent to accomplish the task. There are also many other observations which may be made in balloon ascents which may prove of very great value. Prof. W. Thomson is anxious that observations should be made on the electrical condition of the atmosphere. He has described in the article on the Electricity of the Atmosphere in Nichol's 'Cyclopædia,' a portable electrometer, and also a mode of collecting electricity by that which he styles the water-dropping system, which would, in his opinion, be easily applicable. The observations might be carried on, first, by ascending to very moderate heights, and then going as high as possible. Dr. Lloyd desires that observations should be made for "the determination of the decrease of the earth's magnetic force with the distance from the surface." The failure of Gay-Lussac to detect any sensible change ought not to deter future observers. His methods were wholly inadequate; but Dr. Lloyd is of opinion that if attention be confined to the determination of the total force or its vertical component (instead of the horizontal), it would be easy to arrive at satisfactory conclusions. Sir David Brewster suggests that further information may be obtained as to the polarization of the atmosphere and the height of the neutral point. And, lastly, Dr. Edward Smith and Prof. Sharpey are desirous that experiments should be made as to "the quantitative determination of the products of respiration at different high elevations." Dr. Smith has, as it is well known, been for the last two or three years engaged in experimental inquiries on inspiration, and he is so satisfied of the value and importance of the investigation, that he is not only willing, but desirous to make the requisite experiments himself. Dr. Smith has furnished directions as to the points to be observed and the mode of observation.

Report of Committee appointed to prepare a Self-Recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity. By Professor W. THOMSON, *F.R.S.*

YOUR Committee, acting according to your instructions, applied to the Royal Society for £100 out of the Government grant for scientific investigation, to be applied to the above-mentioned objects. This application was acceded to, and the construction of the apparatus was proceeded with. The progress was necessarily slow, in consequence of the numerous experiments required to find convenient plans for the different instruments and arrangements to be made. An improved portable electrometer was first completed, and is now in a form which it is confidently hoped will be found convenient for general use by travellers, and for electrical observation from balloons. A house electrometer, on a similar plan, but of greater sensibility and accuracy, was also constructed. Three instruments of this kind have been made, one of which (imperfect, but sufficiently convenient and exact for ordinary work) is now in constant use for atmospheric observation in the laboratory of the Natural Philosophy Class in the University of Glasgow. The two others are considerably improved, and promise great ease, accuracy, and sensibility for atmospheric observation, and for a large variety of electrometric researches. Many trials of the water-dropping collector, described at the last Meeting of the Association, were also made, and convenient practical forms of the different parts of the apparatus have been planned and executed. A reflecting electrometer was last completed, in a working form, and, along with a water-dropping collector and one of the improved common house electrometers, was deposited at Kew on the 19th of May. A piece of clockwork, supplied by the Kew Committee, completes the apparatus required for establishing the self-recording system, with the exception of the merely photographic part. It is hoped that this will be completed, under the direction of Mr. Stewart, and the observations of atmospheric electricity commenced, in little more than a month from the present time. In the mean time preparations for observing the solar eclipse, and the construction of magnetic instruments for the Dutch Government, necessarily occupy the staff of the Observatory, to the exclusion of other undertakings. It is intended that the remaining one of the ordinary house electrometers, with a water-dropping collector, and the portable electrometer referred to above, will be used during the summer months for observation of atmospheric electricity in the Island of Arran. Your Committee were desirous of supplying portable apparatus to Prof. Everett, of Windsor, Nova Scotia, and to Mr. Sandiman, of the Colonial Observatory of Demerara, for the observation of atmospheric electricity in those localities; but it is not known whether the money which has been granted will suffice, after the expenses yet to be incurred in establishing the apparatus at Kew shall have been defrayed. In conclusion, it is recommended to you for your consideration by your Committee, whether you will not immediately take steps to secure careful and extensive observations in this most important and hitherto imperfectly investigated branch of meteorological science. For this purpose it is suggested,—1. that, if possible, funds should be provided to supply competent observers in different parts of the world with the apparatus necessary for making precise and comparable observations in absolute measure; and 2. that before the conclusion of the present summer a commencement of electrical observation from balloons should be made.

Experiments to determine the Effect of Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders. By WILLIAM FAIRBAIRN, *Esq., LL.D., F.R.S.*

AMONGST engineers opinions are still much divided upon the question, whether the continuous changes of load which many wrought-iron constructions undergo, has any permanent effect upon their ultimate powers of resistance; that is, whether a beam or other construction subjected to a perpetual change of load, would suffer such an alteration in the structure of the iron or the tenacity of the joints, that it would in time break with a much less force than its original breaking weight. But few facts are known, and few experiments have been made bearing on the solution of this question. We know that in some cases wrought iron subjected to continuous vibration assumes a crystalline structure, and is then deteriorated in its cohesive powers; but we are yet very ignorant of the causes of this change, and of the precise conditions under which it occurs.

A few experiments were made by the Commission appointed to inquire into the application of iron to railway structures, to ascertain the effect of changes of load upon homogeneous bars of wrought and cast iron. They found with cast iron that no bar would stand 4000 impacts, bending them through one-half of their ultimate deflection, but that sound bars would sustain at least 4000 impacts, bending them through one-third of their ultimate statical deflection. They ascertained also, that when the load was placed upon the bars without impact, if the deflection did not exceed one-third of the ultimate deflection, the bar was not weakened; but that if the deflection amounted to one-half the ultimate deflection, the bars were broken with not more than 900 changes of load. With wrought iron bars they found no perceptible effect from 10,000 changes of load, when the deflections were produced by a weight equal to half the statical breaking weight.

These experiments are interesting so far as they go, but they are very incomplete as regards wrought iron. For wrought-iron bars they were not continued long enough, nor do they apply to those larger constructions in which the homogeneous bar is replaced by riveted plates. The influence of change of load on riveted constructions possesses a special importance, from its bearing on the question of the proper proportion of strength in plate and tubular bridges. Do these constructions gradually become weakened from the continual passage of trains? and is it requisite to make allowance for such a deterioration by increased sectional area of material in their original construction? These questions I have sought to solve by the following experiments.

As the load is brought upon bridges in a gradual manner, the apparatus is designed to imitate as far as possible this condition. A riveted beam is fixed on brickwork supports, 20 feet apart. Beneath this is placed a lever grasping the lower web of the beam, and fastened upon a pivot at the fulcrum. At the other extremity it carries the scale and weights. This lever is lifted clear of the beam, and again lowered upon it by means of a connecting rod attached to one of the arms of a spur-wheel placed at a considerable distance overhead. In this way any required part of the breaking weight can be lifted off and replaced upon the beam alternately by the revolution of the spur-wheel. The apparatus is worked night and day by a water-wheel, and the number of changes of load is registered by a counter.

The girder subjected to vibration in these experiments is a plate girder of 20 feet clear span, and of the following dimensions:—

	Sq. in.	
Area of top: 1 plate, 4 in. × $\frac{1}{2}$ in.	2·00	
" 2 angle-irons, 2 × 2 × $\frac{5}{16}$	2·30	
		4·30
Area of bottom: 1 plate, 4 in. × $\frac{1}{4}$ in.	1·00	
" 2 angle-irons, 2 × 2 × $\frac{3}{16}$	1·4	
		2·40
Web, 1 plate 15$\frac{1}{4}$ × $\frac{1}{8}$		1·90
Total sectional area		8·60

Depth	16 in.
Weight	7 cwt. 3 qrs.
Breaking weight (calculated)	12 tons.

This beam having been loaded with 6643 lbs., equivalent to one-fourth of the ultimate breaking weight, the experiment commenced.

TABLE I.—Experiment on Wrought-iron Beam with a changing load equivalent to one-fourth of the breaking weight.

Date, 1860.	Number of changes of load.	Deflection produced by load.	Remarks.
March 21	0	0·17	
" 22	10,540	0·18	
" 23	15,610	0·16	
" 24	27,840	......	Strap loose and failing to lift the weight.
" 26	46,100	0·16	
" 27	57,790	0·17	
" 28	72,440	0·17	
" 29	85,960	0·17	
" 30	97,420	0·17	
" 31	112,810	0·17	
April 2	144,350	0·16	
" 4	165,710	0·18	
" 7	202,890	0·17	
" 10	235,811	0·17	
" 13	268,328	0·17	
" 14	281,210	0·17	
" 17	321,015	0·17	
" 20	343,880	0·17	Strap broken.
" 25	390,430	0·17	
" 27	408,264	0·16	
" 28	417,940	0·16	
May 1	449,280	0·16	
" 3	468,600	0·16	
" 6	489,769	0·16	
" 7	512,181	0·16	
" 9	536,355	0·16	
" 11	560,529	0·16	
" 14	596,790	0·16	

As the beam had now undergone above half a million changes of load, that is, it had worked continuously for two months, night and day, at the rate of about eight changes per minute, and as it had undergone no visible alteration, the load was increased from one-fourth to two-sevenths of the statical breaking weight, and the experiment proceeded with till the number of changes of load reached a million.

TABLE II.—Experiment on the same Beam with a load equivalent to two-sevenths of the breaking weight, or nearly $3\frac{1}{2}$ tons.

Date, 1860.	Number of changes of load.	Deflection in inches.	Remarks.
May 14	0	0·22	In this Table the number of changes of load are counted from 0, although the beam had already undergone 596,790 changes, as shown in the preceding Table.
" 15	12,623	0·22	
" 17	36,417	0·22	
" 19	53,770	0·21	
" 22	85,820	0·22	
" 26	128,300	0·22	
" 29	161,500	0·22	
" 31	177,000	0·22	
June 4	194,500	0·21	
" 7	217,300	0·21	
" 9	236,460	0·21	
" 12	264,220	0·21	
" 16	292,600	0·22	
" 26	403,210	0·23	The beam had now suffered a million changes of load.

Table III.—Experiment on the same Beam with a load equivalent to two-fifths of the breaking weight.

Date, 1860.	Number of changes of load.	Deflection in inches.	Remarks.
June 27	0	0·35	
" 28	5175	...	Broke.

The beam broke after 5175 changes with a load equivalent to two-fifths of the breaking weight, although with lesser weights it had appeared uninjured.

Summary of Results.

Table.	Ratio of load to breaking weight.	Number of changes with each load.	Total number of changes of load.	Deflection in inches.	Remarks.
I.	1 : 4·0	596,790	596,790	0·17	
II.	1 : 3·4	403,210	1,000,000	0·22	
III.	1 : 2·5	5,175	1,005,175	0·35	Broke.

Since these experiments were made the beam has been repaired, and has made 1,500,000 additional changes with a load equivalent to one-fourth of the breaking weight without giving way. It would appear, therefore, that with a load of this magnitude the structure undergoes no deterioration in its molecular structure; and provided a sufficient margin of strength is given, say from five to six times the working load, there is every reason to believe, from the results of the above experiments, that girders composed of good material and of sound workmanship are indestructible so far as regards mere vibratory action.

As the experiments on this important subject are still in progress, we hope to bring the subject more in detail before the Association at its next Meeting.

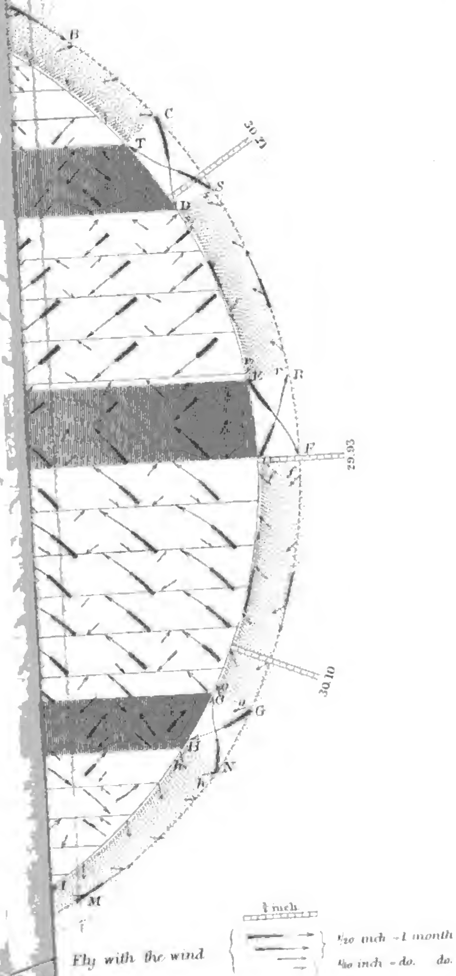
A Catalogue of Meteorites and Fireballs, from A.D. 2 *to* A.D. 1860.

By R. P. Greg, *Esq., F.G.S.*

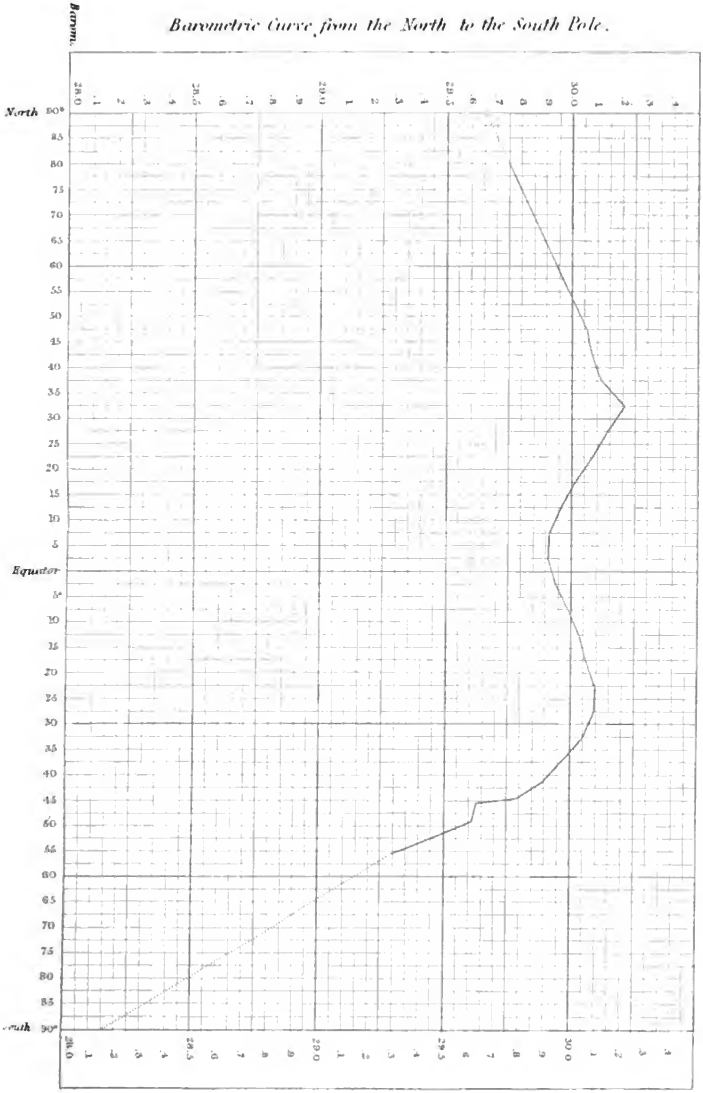
1. This Catalogue is intended partly as a sequel to the Reports on Luminous Meteors, now continued for a series of years in the volumes of the British Association Reports, and partly as a continuation, in a corrected and extended form, of a Catalogue of Meteorites published by the author, in two papers on the same subject, in the Numbers of the Philosophical Magazine and Journal of Science for November and December 1854.

2. The following works and periodicals have been consulted, viz.—Thomson's Meteorology, 1849; Transactions of the Royal Society; Nicholson's Journal of Natural Philosophy; Thomson's Annals of Philosophy; London, Edinburgh, and Dublin Philosophical Magazine; Brewster's Encyclopædia, article "Meteorite;" Annual Register; Journal of the Asiatic Society of Bengal; British Association Reports; Proceedings of the Royal Irish Academy; Spurgeon's Annals of Electricity; New Edinburgh Philosophical Journal; Partsch's, Shepard's, and Reichenbach's Catalogues of Meteorites; R. Wolf's, Chladni's, Boguslawski's, Quetelet's, Baumhauer's, and Coulvier-Gravier's Catalogues; Dr. Clark's Thesis on Iron Meteoric Masses; Poggendorff's Annalen; Annales de Chimie et de Physique; Comptes Rendus; Transactions of the Imperial Academy of Arts and Sciences of Vienna, 1859–60, papers by W. Haidinger; Transactions of the Royal Academy of Brussels; Quarterly Journals of the Natural History Society of Zurich, 1856; Die Feuermeteore insbesondere die Meteoriten, &c., von Dr. Otto Buchner of

Plate 1.


B
C
T
30.23
S
D
E
R
F
29.93
f
30.10
G
H
N
I
M
1 inch
Fly with the wind
1/20 inch = 1 month
1/40 inch = do. do.

Barometric Curve from the North to the South Pole.



Barometric Curve from the North to the South Pole.

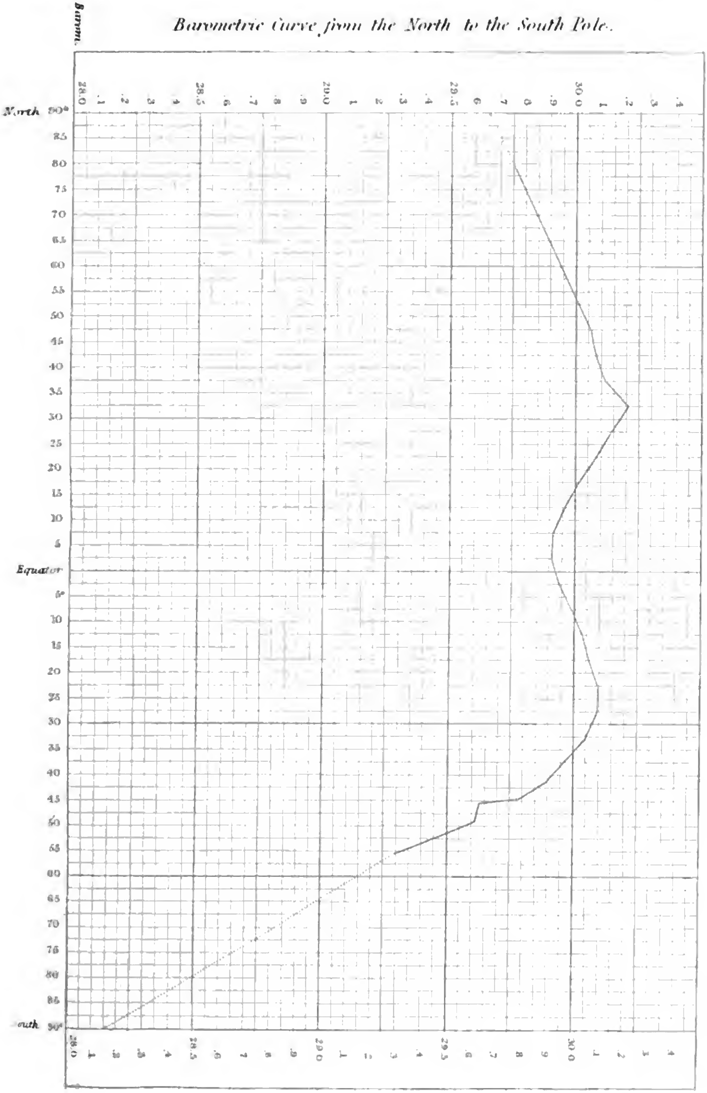
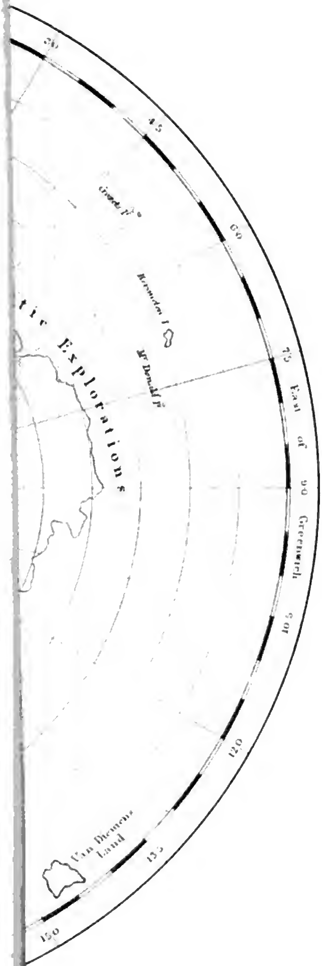


Plate 3.


30
45
Crozet I's
60
Kerguelen I
tic Explorations
Mc Donald I's
75
East of
90
Greenwich
105
120
Van Diemens Land
135
150

Giessen, 1859; Lithologia meteorica del Profesor Joaquin Balcells, Barcelona, 1854; Report on Meteorites, by Prof. Shepard; Reports of the Smithsonian Institution, United States; Silliman's American Journal; as well as various private notices and public journals. I have likewise to acknowledge the kind assistance and valuable information received from Herr P. A. Kesselmeyer, Dr. Buchner, Herr W. von Haidinger, and Professor Heis.

3. The few abbreviations used in this Catalogue speak for themselves, and hardly need explanation. Where weights of meteorites are stated, it is generally intended to denominate lbs. Troy, English, though sometimes the Vienna or Prussian pound has unavoidably been given. Tables of analysis are added at the end of the catalogues. Genuine cases of stone- or iron-falls and detonating meteors, are marked with an asterisk (*), and in the Tables count for 1; doubtful cases are marked in the Catalogue with a (?), and count as ½ in the Tables.

The numbers in some of the Tables, it will be found, do not quite agree with those in the corresponding Tables given in the Report on Luminous Meteors, in the Volume of the British Association Reports for 1860, owing to the circumstance that when that Report was presented at the Oxford Meeting the present Catalogue was not then quite completed.

4. A few remarks are added to the Tables, which do not call for much comment in this place, as they have mostly already been alluded to in the aforesaid Report. With regard to the November period for shooting stars, E. C. Herrick, of the United States, considers it to be advancing into the year; in A.D. 1202, it occurred about the 26th October; in 1366 on October 30th; so that the motion of the node of the zone or ring which furnishes these shooting stars, is at the rate of 3 or 4 days a century; the period itself being a recurrent one probably of about 33 years. (See Silliman's Journal, No. 91, p. 137, for January 1861.)

5. In the Catalogue itself great care has been taken in separating the different kinds of fireballs and aërolites; hitherto this has not been done with sufficient care, and large meteors have not unfrequently been called aërolitic, when not even any detonation has been reported; examples of this not unfrequently occur in the catalogues of Baumhauer, Kämtz, and Arago. Dr. Buchner of Giessen, and P. A. Kesselmeyer of Frankfort-on-Maine, will, I understand, shortly bring out catalogues of aërolitic falls, where details in matters concerning original authorities and geographical distribution, &c. will be given very fully.

In the Tables at the end of this Catalogue, Class A includes only cases where stones or irons have really fallen; Class B, meteors accompanied by detonation; Class C, first-class meteors *not* accompanied by detonation; this class includes all fireballs given in the catalogues up to the year 1820; after that time, only the most remarkable ones, as in consequence of the subsequent greatly increased number of observations from about that time, it is evident the described fireballs would probably be of smaller size than for older observations; Class D includes all fireballs mentioned in the catalogues and supplements, large or small, where no detonation was reported, and of course includes the C class. The Tables are so constructed, that a glance will suffice to show the results as regards numbers and dates, and the proportion which one class bears to another; some of them will be found to be not without some interest.

Note.—Wherever the words "Stone-fall" or "Iron-fall" occur, it may be understood, as a rule, that such phenomenon was also accompanied by a detonating fireball, or at least by a detonation.

Catalogue of Aërolites and Bolides, from A.D. 2 to A.D. 1860.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
A.D. 2.*	?	China	....	....	....	Stone-fall.
1-50.*	?	Dauphine	....	....	....	ditto; during the first half of the first century.
166.*	?	China	....	....	....	ditto.
154.*	?	ditto	....	....	....	ditto.
310.*	?	ditto	....	....	....	ditto.
333.*	?	ditto	....	....	....	ditto.
416.?	?	Constantinople	....	....	....	ditto; according to Arago, a common stone or fallen pillar.
452.*	?	Thrace	....	....	....	ditto.
481.*	?	Africa	....	....	....	ditto.
550.*	?	Syria, near Emessa	....	....	....	ditto (6th century).
570.*	?	Bender, Arabia	....	....	....	ditto; many stones fell.
584.	Dec.	France?	large	....	....	fireball; = daylight.
585.*	Oct. 23	ditto?	ditto	....	....	ditto, followed by a loud detonation.
587.*	Jan. 1	ditto	ditto	....	....	ditto ditto.
590.?	March	?	....	....	....	ditto.
616.*	?	China	....	....	....	Stone-fall; several stones fell.
650.*	?	?	....	....	....	ditto.
852.*	July or Aug.	Daghestan	....	....	....	ditto.
823.*	?	Saxony	....	....	....	ditto; many small ones fell.
837.*	?	?	....	....	....	ditto.
839.	Feb. 21	France?	....	....	....	fireball, tailed.
856.*	Dec.?	Soweida?, Egypt	....	....	....	Stone-fall.
886.*	?	Japan	....	....	....	ditto (A.D. 885 or 887).
892.*	?	Ahmed-Abad, Mesopotamia	....	....	....	ditto, or A.D. 897. Stones brought to Bagdad.
897.?	?	Kusah	....	....	....	ditto. Same as the last probably.
905.*	?	Corea, China	....	....	....	ditto? (or A.D. 903); a detonating meteor.
921.*	?	Narni, Italy	large	....	....	ditto.
925.*	May 2	Arabia	ditto	S. to N.	....	fireball and detonation.
	Sept. 21	Egypt	ditto	N.N.W. to S.S.E.	....	ditto, red; serpentine tail.
952.*	?	Augsburg	....	....	....	Stone-fall, or A.D. 951.
956.*	?	Italy	....	....	....	Stone-fall.
970.*	Oct. 5	?	= sun	....	....	fireball, followed by a great noise.
963.*	?	Italy	....	....	....	Stone-fall.
991.	4	Morocco?	large	E. to W.	....	extraordinary meteor.

998.*	?	Magdeburg	....	....	....	Stone-fall; two large ones fell.
990.	Jan.	?	large	....	....	fireball and fiery tail (December ?).
1000.	Mar. 29	?	....	....	....	fireball.
[a]1002.?	Sept. 14	Morocco ?	= moon	....	....	aërolitic meteor (Baumhauer's Catalogue).
	Dec.	France ?	....	....	....	fireball.
1009.*	?	Djorjan, India	2000 lbs.	....	....	Iron-fall ? (Caspian Sea ?; Boguslawski).
1013.	Mar. 16	Morocco ?	large	E. to W.	streak 15′	brighter than the moon.
[b]1021.?	July or Aug.	Africa	....	....	....	Stone-fall (Persia ?). 1820 ?.
1029.*	July 16	Morocco ?	large	....	....	meteoric light and great noise.
1034.?	?	?	....	....	....	Stone-fall ?.
[c]1057.*	?	Corea	....	....	....	aërolitic ?
1075.	18	Morocco ?	large	....	....	fireball.
1076.*	?	Denmark	....	....	....	Stone-fall (Boguslawski's Catalogue).
[d]1093.?	April 10	Paris ?	....	....	....	aërolitic (Baumhauer's Catalogue), or 1st April.
	Sept. 1	?	....	....	....	fireball, or August 5 ?.
1109.	?	?	....	....	....	fireball.
1110.?	?	Lake Van, Armenia	....	....	....	Stone-fall ?.
1112.*	?	Aquileia, Trieste	....	....	....	ditto.
1135.*	?	Oldesleben, Thuringia	....	....	....	ditto; 10 inches diameter (or A.D. 1136).
[e]1138.?	March 8	Mosul, Asia Minor	....	....	....	aerolitic (Baumhauer's Catalogue).
1164.*	May	Misnia, Saxony	....	....	....	Iron-fall ?. About the feast of Pentecost.
[f]1186.*	June 30	Mons, Belgium	....	....	....	several stones fell; some of 1 lb. weight.
1189.?	?	?	....	....	....	aërolitic fall; Boguslawski's 10th Supp. to Chladni.
1191.?	?	?	....	....	....	ditto ditto ditto.
1194.?	?	?	....	....	....	ditto ditto ditto.
1197.?	?	?	....	....	....	ditto ditto ditto.
1198.?	July	Paris	....	....	....	aërolitic fireball ?.
1199.	Oct. 23	?	....	....	....	fireball.
1249.*	July 26	Quedlinburg	....	....	....	Stone-fall; many ?.
1257.*	?	Wurzburg, Saxony	....	....	....	ditto; about Whitsuntide.
1280.*	?	Alexandria	....	....	....	ditto ?.
1251–1360*	?	Welikoi-Usting, Russia	....	....	....	ditto.
1300.*	?	Arragon, Spain	....	....	....	ditto; several. About A.D. 1300.
1304.*	Oct. 1	Saale, Saxony	....	....	....	ditto ditto; Friedland or Friedberg.
[g]1305.?	?	Vandal towns	....	....	....	ditto ?; in Lusatia (Saxony).

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[a] 1002*, &c. Morocco = Mauritania, or empire of Morocco; perhaps included Spain.

[b] 1021 or 1020.? July or August. Not improbably hailstones.

[c] 1057*; at Hoanglie, in Corea.

[d] 1093.* April 10th (or 1st); or A.D. 1094. Many shooting stars seen, and a very large one said to have been found on the ground as a glowing substance.

[e] 1138.? March 8. Fiery coals said to have fallen.

[f] June 30, 1186. July 8 is likewise given by some; perhaps N. Style; also A.D. 1187; Bergen is the old name for Mons, and so given by Baumhauer.

[g] 1305.? Vandal towns; probably same as October 1, 1304.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1307.	Feb. 26 ...	?	....	....	....	fireball. 24th February ?.
1325.	May 22 ...	Florence	....	....	....	fireball.
1328.*	Jan. 9 ...	Mortahiah	....	....	....	Stone-fall.
[a]1339.?	July 13 ...	Silesia	....	....	....	aërolitic (Baumhauer's Catalogue).
1340.*	? ...	Aidin, Asia Minor	....	....	....	Stone-fall; one fell A.D. 1340, not A.D. 1440.
1352.	Oct. 22 ...	Italy	....	....	....	fireball.
1353.	Aug. 11 ...	ditto	....	....	....	ditto.
1358.*	? ...	China	....	....	....	Stone-fall.
1354.	May 1 ...	Italy	....	....	....	fireball.
1360.*	? ...	Yorkshire	....	....	....	Stone-fall.
1368.*	? ...	Oldenburg	....	....	....	Iron-fall.
1379.*	26 ...	Minden, Hanover	....	....	....	Stone-fall.
1421.*	? ...	Java	....	....	....	ditto.
1438.*	? ...	Burgos, Spain	....	....	....	many light vesicular stones; day-time at Roa.
1465.	Sept. 22 ...	Paris	large	....	....	fireball.
	Nov. 18 ...	France	....	....	....	ditto.
1474.*	? ...	Viterbo, Italy	....	....	....	Stone-fall; two large stones fell.
1480.*	? ...	Saxony or Bohemia	....	....	....	ditto.
1491.*	15 ...	Ho-nan, China	....	....	....	ditto.
*	Mar. 22 ...	Crema, N. Italy	....	....	....	Stone-fall.
1492.*	Nov. 7 ...	Ensisheim, Bâsle	270 lbs.	....	11½ A.M.	Stone-fall; one large one; 2 P.M.?
1496.*	Jan. 28 ...	Cesena, Romagna	....	....	9 A.M.	ditto; three stones; 26th January ?.
	July 13 ...	Munchberg	....	....	....	fireball. Chladni thinks only hail.
1499.	Apr. 19 ?...	Lucern	large	....	....	fireball.
1510.?	? ...	Padua	....	....	5 P.M.	Stone-fall ?; perhaps = next.
1511.*	Sept. 4 ...	Crema, N. Italy	....	....	....	Stone-fall; many from 1 lb. to 8 lbs.
[b] 1516.*	? ...	River Abdua, China	....	....	....	Stone-fall; 1200 said to have fallen, some 120 lbs.
1516.?	? ...	China	....	....	....	ditto; several from 1 to 27 lbs.
1520.	? ...	Brussels	....	....	....	ditto; before the year 1520.
*	May ...	Arragon, Spain	20 lbs.	....	....	ditto; several.
1528.*	June 29 ...	Augsburg	....	....	....	ditto.
[c]1540.?	April 28 ...	Limousin, France	....	....	....	Stone-fall.
*	June 14 ...	China	....	....	....	Stone-fall.
[d]1545.*	? ...	Neuhof, Saxony	....	....	....	Iron-fall; fell or found ?.
1547.	Apr. 29 ...	Halberstadt	large	....	....	fireball (also seen at Paris).
	Dec. 15 ...	Hamburg	ditto	....	....	ditto.
[e]1548.*	Nov. 6 ...	Mansfeld, Thuringia	½ moon	W. to E.	2 A.M.	detonating meteor; aërolitic? (Baumhauer).
1552.*	May 19 ...	Thuringia, Saxony	....	....	....	Stone-fall.
1554.	Mar. 9 ...	Chalôns	large	....	....	fireball.

1553.	Mar. 13 ...	Thuringia	large	....	....	fireball; tailed.
1557.	20 ...	Chalöns	....	....	....	ditto.
*	Nov. 25 ...	Italy	....	....	....	aërolitic.
[f]1559.*	? ...	Hungary	....	....	....	Stone-fall.
[g]1560.?	Dec. 24 ...	Lillebourne	....	....	....	meteor?: set fire to a magazine in the day-time.
1561.*	May 17 ...	Eilenborg, Torgau	39 lbs.	....	....	Stone-fall, in Prussia. Three fell.
1564.?	Mar. 1 ...	Brussels	....	....	....	aërolitic (according to Baumhauer's Catalogue).
1566.	July 17 ...	?	....	....	....	fireball.
1500–1600.*	? ...	Valencia, Spain	....	....	....	stones fell?; 1520?.
1565.*	3 ...	China	....	....	....	Stone-fall.
1567.*	Nov. 24 ...	Winterthur	....	....	....	large meteor and detonation.
1570.*	Jan. 10 ...	Anspach	....	....	....	ditto, with detonation.
[h]1572.?	9 ...	Thorn	....	....	....	aërolitic (according to Baumhauer's Catalogue).
1577.	Oct. 11 ...	Zurich	....	....	....	fireball.
1580.*	May 27 ...	Göttingen?	....	....	2 P.M.	Stone-fall; several fell.
1581.*	July 26 ...	Thuringia	39 lbs.	....	1½ P.M.	ditto; one stone.
1583.*	Jan. 9 ...	Castrovillari, Italy	30 lbs.	....	....	ditto ditto.
*	Mar. 2 ...	Piedmont	....	....	....	ditto; day-time.
1584.	Feb. 19 ...	?	....	....	....	fireball.
[i]1586.*	Dec. 15 ...	Verden, Hanover	....	....	....	fiery meteor and detonation (December 3, O. S.)?.
1591.*	June 9 ...	Kunersdorf	....	....	....	Stone-fall; several large stones (19th June?).
1596.	Mar. 1 ...	Crevalcore, Piedmont	....	....	5½ P.M.	ditto.
1601.	Sept. 28 ...	Hanau	....	....	....	fireball.
1603.	Aug. 18 ...	Zurich	....	....	....	ditto (August 8, O. S.).
*	Sept. 19 ...	Germany; Zurich	....	....	....	fiery meteor, followed by a detonation.
[j]1618.	Mar. 7 ...	?	....	....	....	fireball.
*	Nov. ...	China	....	....	....	Stone-fall.
*	Aug. ...	Styria	300 lbs.	....	....	Stone-fall (end of August).
1619.	Oct. 5 ...	Frauenfeld	....	....	....	fireball.
1620.*	Apr. 17 ...	Jalindher, Lahore	7 lbs.?	....	....	Iron-fall; 1621?. Fell with great light and noise.
1622.*	Jan. 10 ...	Cornwall, England	....	....	....	Stone-fall; at Tregony. N.B. Not Devonshire.
1623.	Mar. 10 ...	Zurich	....	....	....	fireball (17th March?).

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[a] 1339.? July 13. Silesia. 300 thunderbolts said to have fallen during a thunderstorm; can hardly be considered aërolitic.

[b] {1516.* / 1516.?} China. Possibly the same fall, according to different accounts.

[c] 1540.? April 28. During a hailstorm, stones said to have fallen, one the size of a barrel, entering two ells into the ground.

[d] 1545.* Grimma, Saxony. 1540 according to Boguslawski.

[e] 1548.* November 6. Thuringia; a substance said to have fallen from it like coagulated blood!

[f] 1559.* Hungary. According to Kesselmeyer, 1757. Five large stones fell at Miskolez in Borsehor, four of which were sent to Vienna.

[g] 1560.? December 24. Aërolitic, according to Baumhauer's Catalogue; doubtful meteorite.

[h] 1572.? January 9. Doubtful fall, according to Chladni.

[i] 1586.* December 15. Verden; aërolitic, according to Baumhauer's Catalogue: one account says black and red dust fell.

[j] 1618. End of August. At Muraköz, on the Styrian frontier, three stones fell, each about 100 lbs.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1623.*	Nov. 18 ...	Germany	....	....	....	fireball, and detonation (17th November ?).
1624.	7 ...	Tubingen	....	....	....	fireball.
1627.*	27 ...	Provence, France..............	59 lbs.	....	....	Stone-fall.
1628.*	Apr. 9 ...	Hatford, Berks	24 lbs.+	....	5 P.M.	ditto; accompanied by detonations.
1629.	4 ...	Tubingen	....	....	....	fireball.
1635.	June 21 ...	Vago, Verona	large	N. to S.	....	Stone-fall, night-time. =1668.
*	July 7 ...	Calce, Vicenza	11 ozs.	....	....	Stone-fall; Italy.
1636.*	Mar. 6 ...	Sagan, Silesia	....	....	6 A.M.	Stone-fall; one large one.
*	Dec. ...	Cüstrinensi Territory?	large	....	....	great fiery globe, and terrific sound.
1637.	Oct. 3 ...	France	....	....	....	fireball.
[a] *	Nov. 29 ...	Mount Vaison, France	38 lbs.	....	10 A.M.	Stone-fall; one fell. Specific gravity 3·5.
1640.	Apr. 4 ...	Holland	....	....	....	fireball. [1007.
1642.*	Aug. 4 ...	Suffolk co., England	4 lbs.	....	4½ P.M.	Stone-fall, near Woodbridge. Gent. Mag., 1796, p.
[b] *	Dec. 12 ...	Ofen, Hungary	....	....	....	Stone-fall or iron-fall? (Chladni).
1643.	Feb. 6 ...	Glarus	....	....	....	meteor.
[c]1647.?	? ...	Rochefort........................	8 lbs.	....	....	Stone-fall; fell on ship-board, killing two men.
*	18 ...	Zwickau, Saxony	50 lbs.	....	night	Stone-fall.
*	Aug. ...	Stolzenau, Germany	....	....	....	Stone-fall; several fell in Westphalia.
1648.	Jan. 8 ...	Naples	....	....	....	fireball; or 10th January.
	Mar. 15 ...	Reutlingen	....	....	....	ditto.
1649.	May 11 ...	Alsace	....	....	....	ditto.
	Sept. 1 ...	Hamburg	....	....	....	ditto; moved in bounds up and down.
1650.*	Aug. 6 ...	Dordrecht, Holland	....	....	....	Stone-fall; one fell.
1651.	Jan. 7 ...	Switzerland	....	....	....	fireball.
1654.*	Mar. 30 ...	Fünen Island, Denmark	....	....	8 A.M.	Stone-fall; many fell.
*	Sept. 4 ...	Milan	....	....	....	ditto (1650?).
1660.	Feb. 23 ...	Wittenberg	....	....	....	fireball.
1662.	Apr. 26 ...	Königsberg	....	....	....	ditto.
1663.	Mar. 13 ...	Malmöe, Sweden...............	....	....	....	ditto.
	May 14 ...	Chiloe, South America	large	....	....	ditto.
1664.	Apr. 8 ...	Saxony............................	....	....	....	ditto.
	Aug. 3 ...	Hungary	large	....	....	left a bright streak or train of light.
	Dec. 18 ...	Croatia............................	....	....	....	a fiery meteoric phenomenon seen.
1666.	July 17 ...	Italy?	....	....	....	fireball.
[d]1668.?	June 20 ...	Verona, Italy	200+300 lbs.	....	night	Stone-fall; many fell.
1671.*	Feb. 27 ...	Swabia, Austria	9+10 lbs.	....	....	ditto ditto; night-time.
1673.*	? ...	Dietling, Bavaria	....	....	....	Stone-fall, at Baden? (Boguslawski's Catalogue).
1674.*	Oct. 6 ...	Glarus, Switzerland	....	....	....	ditto; a large one.
1676.	Jan. 24 ...	Switzerland	....	....	....	fireball.

1676.	Feb. 21	Switzerland	....	....	....	ditto.
[e] *	Mar. 31	Italy; Dalmatia	2 > moon	E. to W.	7 P.M.	fell into the sea near Corsica; detonation.
	Apr. 8	Monte Pulciano	....	....	....	fireball.
	Sept. 20	England	....	....	....	ditto.
*	?	Orkneys	....	....	....	Stone-fall; fell into a boat.
1677.*	May 28	Ermendorf	....	....	evening	Stone-fall; several fell. Saxony.
1678.	Feb. 6	Frankfort-on-Maine	....	....	....	fireball.
	Sept. 2	Glarus	....	....	....	ditto (September 13 ?).
1680.*	May 18	London	2½ in. *d.*	....	....	Stone-fall; several fell near Gresham College.
	June 1	Leipzig	....	....	....	fireball; 22nd May, O. S.?
	Dec. 17	Courland	....	....	....	ditto.
1682.	May ?	Germany	....	....	....	ditto; seen at many places.
	June ?	Rochlitz	....	....	....	ditto.
1684.	May 19	Annaberg	....	....	....	fireball.
	Nov. 13	Gottesgabe	....	....	....	ditto.
	17	Brittany	....	....	....	ditto.
1685.	Aug. 22	Germany	....	....	....	ditto.
1686.	July 19	Germany; Leipzig	¼ moon	E. to W.	7′	stationary for 7′; gradually vanished; 30 miles high.
1687.	May 22	Paris	....	....	....	fireball.
1688.	Apr. 17	Heilbrönn	....	....	....	ditto.
1689.*	Oct. 1	Boston, United States	....	....	....	brilliant bolide; detonation afterwards.
1690.*	Jan. 2	Jena	....	....	....	aërolitic (according to Baumhauer's Catalogue).
1692.*	Apr. 9	Temesvar, Hungary	....	....	....	fireball, accompanied by detonation; (Chladni).
1697.*	Jan. 13	Pentolina, Siena	....	....	5 P.M.	Stone-fall; several. Italy.
[f] 1698.*	May 19	Waltringen, Berne	....	....	7½ P.M.	Stone-fall; a large one.
1700.	Jan. 7	Normandy	....	....	....	fireball.
[g] *	Autumn	Jamaica	....	....	....	large meteor; aërolitic ?.
1704.*	Dec. 25	Barcelona, Spain	....	S.E. to N.W.	5 P.M.	Stone-fall; Poggendorff, viii. 1826, p. 46. Several.
1706.	Mar. 20	England	....	....	....	fireball.
*	June 7	Larissa, Macedonia	72 lbs.	....	....	Stone-fall.
1708.	July 31	Sheerness	....	N.E. to S.W.?	....	fireball; 50 miles above Sheerness.
1709.	Dec. 7	Zurich	....	....	....	ditto.
1710.	May 18	Leeds; Nottingham	large	....	....	bright as moon (17th May ?, 12th May ?).

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[a] **1637 or 1639.* November 29, on Mount Vaison in Provence.**

[b] **December 12.* Between Ofen and Gran.**

[c] **1647.* Rochefort; it is not stated which Rochefort, probably in France, west coast. It is also stated that at Roquefort, in America ?, a stone once fell through the roof of a cottage and killed two men by the roof falling in, having first made a hole of 5 feet in diameter. See Athenæum for 1836, p. 803. Accounts evidently confused.**

[d] **1668.* June 20, or 19th July ?. Near Vago.**

[e] **1676.* March 31 (21st O. S.). Copinsha, &c., as well as Dalmatia and** Leghorn; from 174 miles high to 40: **hissing sound heard when it fell into** the sea; probably aërolitic. **A remarkable meteor; burst with a loud report.**

[f] 1698.* May 19, May 17 ?. **Berne, Zurich, or 27th N. S. " Wolf."**

[g] About 1700.* Autumn, **St. Jago de la Vega, Jamaica; large fiery body** fell, making many deep holes **in the ground, but no stones looked for. See** Philosophical Transactions.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1711.*	Mar. 31 ...	Zurich	....	....	....	fireball and detonation.
	11 ...	Switzerland	....	....	....	fireball.
1714.*	Oct. 4 ...	Berne and Zurich	....	....	....	fireball?, with detonation.
1715.*	Apr. 11 ...	Schellin, Pomerania	15 lbs. + ½	....	2 P.M.	Stone-fall; Prussia.
1716.	Mar. 6 ...	England	....	....	....	large bolide.
[a]1717.?	? ...	Hungary	....	....	....	aërolitic fall; Poggendorff, iv. 1854, p. 33.
	Jan. 4 ...	Quesnoy	....	....	....	fireball.
	Aug. 10 ...	Schleswig; Bohemia	....	....	....	ditto.
[b]1718.?	Mar. 24 ...	Lethy, East Indies ..	....	....	1 P.M.	a large fiery mass fell and exploded on the ground.
1719.	Feb. 22 ...	Italy; Zurich	....	....	....	fireball.
[c] *	Mar. 19 ...	England; N. Europe	> moon	N.N.E. to S.S.W.?	....	brilliant; oval; loud detonation over S. of England.
1721.	Jan. 26 ...	Switzerland	....	....	....	fireball.
	Mar. 15 ...	Stutgardt	....	....	....	fine reddish bolide (middle of March).
1722.	Feb. 1 ...	Switzerland	....	....	....	fireball.
*	June 5 ...	Freisingen, Bavaria	....	....	3½ P.M.	Stone-fall.
1723.	Jan. 6 ...	Portugal	....	....	....	fireball.
*	June 22 ...	Plescowitz, Bohemia	....	....	2 P.M.	Stone-fall; 33 picked up, one of 6 lbs.
	Aug. 22 ...	Schleswig	....	....	....	fireball.
1725.*	July 3 ...	Mixbury, Oxfordshire	20 lbs.	....	....	Stone-fall.
	Oct. 22 ...	Maryland	....	....	....	fireball; same as next?. [50 miles round.
[d] *	22 ...	at sea, near Petapsko	....	....	2 P.M.	meteor, followed by a series of detonations, heard for
1726.	Jan. 1 ...	Schleswig	....	....	....	fireball.
	Feb. 4 ...	Regensburg	....	....	....	ditto.
1727.*	July 22 ...	Lilaschitz, Bohemia	....	....	....	Stone-fall; several.
1728.	Mar. 29 ...	Ober-Lausitz	....	....	....	fireball; or 28th March.
	30 ...	Netherlands	....	....	....	ditto; same as last?.
	May 30 ...	Campo-Major	....	....	....	ditto.
	Dec. 4 ...	Nurenberg	....	....	....	ditto.
1729.	Apr. 19 ...	Geneva	....	....	....	ditto.
	June 2 ...	Switzerland	....	....	....	ditto.
	Aug. 23 ...	Paris	....	....	....	ditto.
	Oct. 1 ...	Sweden	....	....	....	ditto.
	16 ...	Warsaw	....	....	....	ditto.
	Nov. 25 ...	Tuscany	....	....	....	ditto.
1730.	Apr. 13 ...	Ober-Schleswig	....	....	....	ditto.
	June 17 ...	Neisse	....	....	....	ditto. July 17?.
	Aug. 20 ...	Ober-Lausitz	....	....	....	ditto.
1731.	Mar. 3 ...	Upsala	....	....	....	ditto.
[illegible] *	12 ...	Halstead, Essex	....	....	....	Stone-fall and fireball.

1732.	Aug. 15	Springfield	....	....	....	fireball.
[f]1733.	Aug.	England	large	E. to W.	....	ditto.
	Nov. 4	France	....	....	....	ditto.
	Dec. 8	S. England; Dorset	....	....	....	ditto, visible by daylight.
1734.	Mar. 13	London	....	....	....	fireball.
	Dec. 9	Regensburg	....	....	....	ditto.
1736.	Oct. ?	Schleswig	....	....	....	ditto.
1737.	Nov.	Löwen?	....	....	....	ditto.
	?	N. America	....	....	....	ditto.
*	May 21	Adriatic Sea	....	....	....	aërolitic (according to Boguslawski's Catalogue).
*	Dec. 5	Kilkenny, Ireland	large	....	....	burst with a loud report.
	30	Grecian Archipelago	....	N. to S.	....	like a fiery cloud.
1738.	July 13	Paris	....	....	....	fireball; kept rising and falling by bounds till it vanished beneath the horizon.
[g] ?	Aug. 18	Carpentras, France	....	....	4½ P.M.	ditto; aërolitic?; no stone found.
	28	England	....	....	....	fireball.
[h] ?	Oct. 18	Avignon	....	....	....	aërolitic? (according to Baumhauer's Catalogue).
1739.*	June 3	Cambridge, New England	....	S. to N.	slow	with detonation; 70 miles high.
	Dec. 2	England	....	N. to S.	....	fireball.
[i]1740.*	Feb. 23	Toulon	....	....	....	aërolitic (according to Baumhauer's Catalogue).
[j] ?	?	Hungary	....	....	....	ditto (according to Boguslawski).
*	Winter	Greenland	large stone	....	....	Stone-fall (Winter of 1740 and 1741).
1741.*	Dec. 11	Sussex; Isle of Wight	> moon	W. to E.	....	conical; train of smoke; detonating fireball.
1742.*	Nov. 24	New Haven, Mass., U. S.	....	S.W. to N.E.	....	fireball, with detonation.
	Dec. 16	London	....	....	....	fireball.
1743.	Oct. 4	London	....	....	several min.	ditto; like a rocket; streak several minutes.
1744.	May 7	Oxford	....	....	....	ditto.
	27	London	....	N.W. to S.E.	slow	low down.
1745.	Jan. 13	Arnheim	....	....	....	fireball.
	Oct. 13	Boulogne	....	....	....	ditto.
1746.	Mar. 8	Essex	....	....	....	ditto (or May 8?).

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[a] 1717.? Hungary; probably only the meteor of August 10, seen in Bohemia, Hungary, Prussia, &c. The Reports of the British Association of 1849, state that a stone fell, but this does not seem to be correct.

[b] 1718.? March 24. Lethy Island. A jelly-like mass, silvery and scaly, said to have been found; according to some authorities, the year 1728.

[c] 1719.* March 19. Seen 65 miles over Hereford; burst? 70 miles high; $v.=350$ miles per minute; $d.=1\frac{1}{4}$ miles; seen all over Northern Europe. Halley calculated it at 150 miles high when first seen; 8000 feet $d.$; $v.=5\frac{1}{2}$ miles in a second. Another account gave 297 miles high.

[d] 1725.* October 22. Flames seen in the zenith for 5′.

[e] 1731.? Lessay, Coutance. Annales de Chimie, vol. lxxxv. p. 276. 1813.

[f] 1732.? August 15. Springfield, England. Aërolitic, according to Baumhauer, but, according to Kämtz, only a fireball, which fell into the Channel.

[g] August 18.? Carpentras and Champfort, near Avignon. See Oct. 18.

[h] October 18.? Avignon. Probably the same as Carpentras, August 18.

[i] 1740.* February 23. Toulon. A fireball, which seemed to fall with detonation into the sea. Buchner says it rose by degrees and then descended again, then bounded back, and exploded at a great height.

[j] 1740.? Hungary. This is not correct; it is a mistake for 1717, according to Kesselmeyer; but more probably for 1770.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
[a]1749.	Nov. 4	Atlantic Ocean	....	....	....	fireball (Lat. 42° N., and Long. 9° W.?).
[b]1750.?	Feb. 9	Silesia	....	....	....	ditto; aërolitic (according to Baumhauer's Cat.).
	Apr. 12	Hamburg	....	....	....	fireball.
	June 7	Norwich	....	....	....	ditto.
	July 16	Italy	....	....	....	ditto.
	22	Peterborough	....	N.W. to S.E.	slow	fine bolide; tailed.
*	Oct. 12	Niort, Normandy	20 lbs.	noon	....	Stone-fall; a large one (or 11th October).
[c]1751.*	May 26	Agram, Croatia	71+16 lbs.	N. to E.	6½ P.M.	Iron-fall; meteor and great explosion.
1752.	June 19	Nismes	....	....	....	fireball.
	Sept. 4	Zurich	....	....	....	ditto, like a rocket.
1753.*	July 3	Tabor, Bohemia	13 lbs.+	....	8 P.M.	Stone-fall; several; sp. gr. 3·65.
*	Sept. 7	Liponas, France	31 lbs.	....	2 P.M.	Stone-fall; two fell; sp. gr. 3·66.
	?	Lapland	....	....	....	fireball.
1754.	Feb. 26	Dublin	large	E. to W.	2″	bright as moon; nearly ⊥ down; no streak or tail.
	Aug. 15	Holland	....	....	....	fireball?; 15 miles high?.
1755.*	July	Terra Nuova	7 lbs.?	....	....	Stone-fall; 7 oz.? In Calabria.
	Nov. 27	Sweden	....	....	....	fireball.
1756.	Jan. 2	Perth	....	....	....	a fine meteor.
	21	England	....	....	....	fireball.
	25	Milverton, Somerset	....	....	....	ditto (or 26th January?).
	Feb. 28	Cologne	....	....	....	ditto.
	Mar. 3	Berne; France	large	....	....	also seen at Vevay, Aigle, and Bâsle.
	Apr. 29	Nevington	....	....	....	fireball.
1757.	Feb. 18	Rouen	....	....	....	ditto.
[d]1758.	Nov. 26	Edinburgh; Dublin	=moon	S. to N.	....	dazzling; light as day, seen all over Great Britain.
	Dec. 22	Colchester	....	....	....	fireball.
1759.	Apr. 4	Bombay	....	....	....	splendid bolide.
	June 15	Bazas	....	....	....	ditto; caused an incendiary fire? (June 13?).
	Oct. 20	Bath, Essex, &c.	=moon	N.W. to S.E.	2″	=moon at Sheffield; =Venus in Essex.
[e]1760.*	May 4	Newfoundland	large	N.E. to S.W.	....	conical; exploded with noise. Possibly the next one.
*	10	New England	ditto	N.E. to S.W.	....	cast a shadow in bright sunshine; detonation.
[f]1761.	Jan. 26	Weiböe	....	....	....	fireball.
*	Apr.	Thessalonica	large	S.E. to N.W.	....	by daylight; burst with great noise. Macedonia.
	July 17	Italy	....	....	....	fireball.
	Oct. 11	Burgundy	....	....	....	ditto; set fire to a barn?; electrical?.
	Nov. 3	Whitby	....	N.E. to S.W.	streak 15′	ditto; accompanied with tail and sparks.
[g] *	13	Geneva	large	....	....	ditto; followed by a detonation.
	11	Chamblans, France	....	....	....	fireball.
1762.	Apr. 30	Sweden	....	....	....	fireball.

1762.*	June 11 ...		....		....	
[h]	July 23 ...	Brandenburg	....	....	....	ditto ;? 87 miles high at first, then 17 miles.
*	Nov. 12 ...	South of France	$\frac{2}{3}$ moon	S.W. to N.E.	....	ditto; large streak left; great detonation after.
	Dec. 5 ...	Bideford, Devon.........	= moon	....	....	ditto; large tail; dazzling; left a curling vapoury smoke.
	27 ...	Sweden	....	....	....	fireball.
1763.	Jan. 13 ...	Sweden	....	....	....	ditto.
	15 ...	Reading	large	....	....	bright as the moon.
	Sept. 2 ...	Sweden, &c.........	ditto	....	....	a vast globe of fire and fiery tail.
	Oct. 18 ...	Bedfordshire	$\frac{3}{4}$ moon	⊥ to W.	26″	fireball (or 1764 ?).
1764.*	July 20 ...	Philadelphia	> sun	S.E. to N.W.	....	30″ after bursting a loud report heard ; brilliant.
	Nov. 19 ...	Paris	....	....	....	fireball.
1765.	May 3 ...	Rome	large	....	....	ditto ; equal sunlight.
	Aug. 9 ...	Greenwich	....	N.W. to S.E.	....	a large bolide.
*	Oct. 8 ...	South of England	= moon	....	....	ditto ; brilliant ; detonation (October 11 ?).
	Nov. 11 ...	Frankfort.........	....	....	....	a bright meteoric light, lasting some time.
1766.*	July 15 ...	Albereto, Milan	....	....	5 P.M.	Stone-fall; a large stone; about the middle of the month.
	Oct. 26 ...	England	....	....	....	fireball.
1768.*	Sept. 13 ...	Lucé, Sarthé, France	7½ lbs.	....	$\frac{1}{4}$5 P.M.	Stone-fall ; several ; sp. gr. 3·58.
*	Nov. 20 ...	Mauerkirchen, Bavaria	38 lbs.+	....	4 P.M.	Stone-fall ; two fell, one of 38 lbs. ; sp. gr. 3·45.
1769.	Jan. 27 ...	Coventry	....	....	....	a ball of fire seen by daylight.
*	June 3 ...	?	....	....	....	fireball and detonation.
[i]1770 *	Oct. 25 ...	Rasgrad	44 lbs.+4½ lbs.	....	....	Stone-fall (the stones sent to Constantinople).
1771.*	July 17 ...	France and England	> moon	....	....	fireball ; 54 miles high ; 24 miles a second ; detonated.
	Nov. 9 ...	Vöringen	....	....	....	fireball.
[j] ?	? ...	Ireland.........	....	....	....	stones said to have fallen.
[k]1772.*	Feb. 10 ...	Berwickshire	$\frac{1}{3}$ moon	N.W. to S.E.	30° in 11″	fireball ; slow ; detonation in 5′ ; conical ; tailed.
	July ? ...	United States ?	....	....	....	ditto.
1773.	July 29 ...	Crespi	....	....	....	ditto.
	Aug. 3 ...	England	....	....	....	ditto.
	8 ...	Northallerton	....	....	....	ditto.

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[a] 1749. November 4. Atlantic Ocean ; probably an electric fireball ; shattered a ship's mast, leaving a strong sulphurous smell.

[b] 1750. ? February 9. Silesia ; a fireball, said to have fallen down in fragments.

[c] 1751.* May 26. Croatia. The vapoury cloud left by the explosion visible for an hour before entirely dissipated. After the detonation took place, two masses of iron fell in the shape of chains welded together. Haidinger has lately published a full account of this fall in one of the Vienna Journals.

[d] 1758. November 26 (or 25 ?). Seen from Cambridge to Ross-shire ; velocity = 30 miles in a second ; height over Cambridge 95 miles ; over Inverness 30 miles : seemed to descend obliquely towards the earth, and then rose again with renewed splendour.

[e] 1760.?* May 4. Newfoundland, St. John's. 1759 ?; possibly the next one.

[f] 1760.* May 10. New England. 1761 ?.

[g] 1761.* November 11. Boguslawski has Chamblans, Oise, France ; aërolitic fall ; possibly same as that said to have been seen and heard at Geneva on the 13th.

[h] 1762. July 23. Brandenburg. 24th July ?.

[i] 1770.* October 25, or at Hasargrad in Turkish Roumelia, A.D. 1740, or 1717 according to some, though incorrectly.

[j] 1771.? A stone like a grey siliceous pebble. Annales de Chimie, vol. lxxxv. p. 278, 1813. Possibly same as 1779 at Pettiswood.

[k] 1772.* February 10. Tweedmouth, &c. Vertical when first seen ; 66 miles distant when noise heard.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1773.*	Nov. 17	Sigena, Arragon	9 lbs.	....	noon	Stone-fall; sp. gr. 3·63. Day-time.
1775.	May 8	Waltham Abbey	....	....	slow	a large meteor.
*	Sept. 19	Rödach, Coburg	6½ lbs.	....	10 A.M.	Stone-fall; Germany.
*	?	Obruteza, Russia	....	....	....	ditto; in Volhynia.
1776.	May 12	Mexico	....	....	....	fireball.
	July 11	Oxford	....	....	....	ditto.
?	Aug. 15	Novellara	large	....	....	ditto; aërolitic? (1766?).
1777.*	Jan. or Feb.	Fabriano, Ancona	....	....	....	Stone-fall; Italy (1776?).
*	Sept. 11	Berne	....	....	....	meteoric light and detonation.
[a]1778.*	Aug. 26	Sondrio, near Como	....	....	....	fireball; detonated.
1779.	Mar. 8	Département de l'Ain	....	....	....	ditto.
	Aug. 5	Pekin	....	....	....	ditto.
	Oct. 31	Philadelphia	....	....	....	ditto; 60 miles high when first seen.
*	?	Pettiswood, Ireland	5 ozs.	....	....	Stone-fall; in Westmeath. 1771?. Gent. Mag., Sept. [1796.
1780.*	Apr. 1	Beeston, Nottingham	....	....	9 P.M.	ditto; April 11?; iron-fall?.
	Nov. 2	New Spain	....	....	....	fireball.
?	?	Lahore, India	....	....	....	Iron-fall; 1620?.
1781.	Apr. 12	Berne	large	....	....	meteor.
1782.*	July	Turin	....	....	....	Stone-fall; one fell.
[b]1783.?	?	France	....	....	....	Stone-fall.
	Aug. 13	Palatinate?	....	E.S.E. to W.N.W.	....	fireball (7th August, O.S.?).
[c] *	18	France, England, Scotland	> moon	N. to S.	75° in 20″	streak visible for 60″; detonation over Lincoln.
	Oct. 4	London, &c.	¼ moon	N.W. to S.E.	....	v. = 12 miles per sec.; 50 miles high; 200 yds. diam.: [Oct. 14?.
1784.	July 30	Prague	⅛ moon	E.S.E. to W.N.W.	....	fireball (24th July, Old Style?).
	Sept. 4	Prague	....	....	....	ditto.
	11	North Italy	....	....	....	ditto; 45 miles high when first seen.
1785.?	Jan. 10	Valence	....	....	....	ditto; aërolitic?.
*	Feb. 19	Eichstadt, Bavaria	....	....	noon	Stone-fall; one 6 inches diam.: sp. gr. 3·62.
	June 1	Florence	....	....	....	fireball.
[d]	Aug. 13	Frankfort-on-Maine	....	....	....	aërolitic (according to Boguslawski's Catalogue).
1786.	Apr. 10	Ireland	....	....	....	fireball.
	June 29	Berne	....	....	....	ditto.
[e]	Sept. 2	South of England	....	....	40′	a bright ball of fire and light lasting 40′.
[f]1787.	11	Edinburgh	= sun	....	....	fireball; or September 1.
*	Oct. 1	Charkow, Ukraine	....	....	3 P.M.	Stone-fall; many fell; sp. gr. 3·50.
1788.	17	Connecticut	....	....	....	fireball.
1790.*	July 24	Barbotan, Landes, Bordeaux	20+10 lbs.	S. to N.	9 P.M.	Stone-fall; many fell; sp. gr. 3·62. Rochefort.
1791.*	May 17	Tuscany	....	....	5 A.M.	ditto.
	Oct. 20	Menabilly, Cornwall	....	....	....	hailstones fell: not meteoric stones, as in Chladni's [Catalogue.

[g]1791.	Nov. 11 ...	Göttingen	....	....	....	fireball. Also at Lilienthal.
1792.	Apr. 18 ...	Lima	....	....	....	ditto.
	July 23 ...	Leipzig	....	....	....	ditto.
	Aug. 28 ...	Peru	....	....	....	ditto; meteoric dust said to have fallen.
	Sept.	Mayence	....	....	....	ditto.
1793.	Jan. 13 ...	England	....	....	....	ditto.
	Sept. 10 ...	Northumberland	....	....	5′	ditto; oval; variable; at first only like Sirius.
1794.	Mar. 28 ...	England	....	....	....	fireball.
*	June 16 ...	Siena, Italy	5½ lbs.+	N. to S.	7 P.M.	Stone-fall; 19 picked up; sp. gr. 3·40.
1795.*	Apr. 13 ...	Ceylon, Indies	....	....	5 P.M.	ditto.
*	Dec. 13 ...	Wold Cottage, Yorkshire	56 lbs.	....	3 P.M.	ditto; sp. gr. 3·70.
1796.*	Jan. 4 ...	Bielaja, Zerkwa, Russia	....	....	....	Stone-fall; several.
*	Feb. 19 ...	Friexo, Portugal	10 lbs.	....	....	Stone-fall; near Evora, river Friexo.
[h]	Mar. 8 ...	N. Germany, &c.	large	N.W. to S.E.	....	fireball; irregular in form; as large as the moon; burst.
1797.	July 13 ...	Göttingen	....	....	....	fireball.
[i]1798.	Mar. 8 ...	Villefranche	....	E. to W.	....	bolide; not less than 7 miles high.
*	12 ...	Salés, France	20 lbs.	....	6 P.M.	Stone-fall; sp. gr. 3·45.
	July 28 ...	England	....	....	....	fireball.
?	Sept. 6 ...	Berne	....	....	....	a loud meteoric explosion overhead.
	22 ...	Kent	....	....	....	fireball.
	Oct. 9 ...	Göttingen, &c.	....	....	streak 15″	ditto; had a serpentine tail.
	Nov. 20 ...	England	....	....	....	fireball.
*	Dec. 13 ...	Benares, India	....	....	8 P.M.	Stone-fall.
	19 ...	Bengal	....	....	....	fireball; same as last ?.
[j]1799.*	Apr. 5 ...	Baton Rouge, Miss., U.S.	large	....	....	ditto, followed by a great detonation; aërolitic ?.
	Sept. 15 ...	England	ditto	N.W. to S.E.	....	brilliant; large blazing tail.

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[a] 1778.? Sondrio; moved by bounds and jerks, exploding every time.

[b] 1783.? France. A stone fell, making an oblique hole in the ground. Annales de Chimie, vol. lxxxv. p. 272.

[c] 1783. October 18, 9¼ A.M. A very celebrated and remarkable meteor. First seen in the Shetland Isles; like the planet Mars; ½ moon, from Mullingar to York; equal 2 full moons over Kent; appeared to burst into two straight over Lincolnshire, with a report 8′ or 9′ heard at Windsor afterwards; visible 20″ at once for an arc of 75°; 60 miles high; 20 miles in a second; tail 10> than body; turned a little to E. after partially bursting; left a streak and sparks; tail not much seen at first, perhaps foreshortened. In Ireland, seen moving parallel to horizon 10° or 12° high. Seen over Burgundy in France; altogether for a distance of 1200 miles. At Greenwich as a double bolide, very brilliant. Heard to explode also over York some minutes after.

[d] 1785. August 13. Frankfort. A simultaneous conflagration of two houses, *supposed* to have been caused by an aërolitic or meteoric fall. Doubtful!

[e] 1786. September 2. During a hurricane of wind.

[f] 1787. September 11. Edinburgh; first moved horizontally, then dropped a little, then rose again, bursting behind a cloud. Pringle imagines this bounding is caused by the elasticity of the atmosphere.

[g] 1791. November 11. Göttingen; had a long curved spindle-shaped tail. 12th November ?.

[h] 1796.* March 8. Dresden, Berlin, &c.; accompanied with detonation a few minutes after bursting; aërolitic, according to Baumhauer's Catalogue; a dark bituminous substance fell according to others.

[i] 1798. March 8. Villefranche. Possibly identical with the fall of stones on the 12th at Salés.

[j] 1799.* April 5. Baton Rouge. Stones said to have fallen.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1799.	Nov. 2 ...	Pocklington	....	....	....	fireball.
	7 ...	Mexico	....	....	....	ditto.
1800.*	Apr. 1 ...	Essex; Steeple-Bumstead	....	S.W. to N.E.	....	fireball; detonation; ⊥down with a hissing sound.
[a]	5 ...	North America	....	S.E. to N.W.	....	great meteor and detonation; stones said to have fallen.
	Aug. 8 ...	ditto	....	....	....	fireball.
	15 ...	Halle	....	....	....	ditto (about middle of August).
1801.*	? ...	Isle aux Tonneliers, or Isle de France	....	....	....	meteor and detonation; aërolitic?.
	June 19 ...	Halle	....	....	....	fireball.
	July 14 ...	Montgaillard	....	....	....	ditto.
	Aug. 26 ...	Département de l'Ain	....	....	....	ditto (end of August).
	Oct. 23 ...	Colchester; Bury St. Edmunds	....	....	....	ditto; aërolitic?.
1802.	Aug. 10 ...	Quedlinburg	....	....	....	ditto.
	Nov. 6 ...	Suffolk	....	....	....	ditto.
[b] ?	Sept. 15 ...	Scotland; Loch Tay	....	....	....	Stone-fall; doubtful: see Monthly Mag., Oct. 1802, p. 290.
*	Oct. 1 ..	Beauvais	....	E. to W.	....	fireball, followed by a detonation.
*	? ...	Allahabad, India	....	....	....	Stone-fall. Poggendorff, 1832, vol. xxiv. p. 223.
[c]1803.	Jan. 21 ...	Silesia	....	....	....	a shooting-star; got larger and larger till it fell to earth.
*	Apr. 26 ...	L'Aigle, France	largest 17 lbs.	S.E. to N.W.	1 P.M.	Stone-fall; 3000 said to have fallen; detonations.
[d] *	May 9 ...	Cambridge	⅔ moon	S.W. to N.E.	streak 30″	fireball; detonation. 2 P.M. Brilliant.
[e] ?	July 4 ..	East Norton, Leicester	....	....	....	Stone-fall?; meteor and detonation; struck a building; [electrical?.
	Sept. 22 ...	Geneva	....	....	....	fireball.
	Oct. 8 ...	at sea?	large	⊥down	streak 60′	ditto; 2nd or 10th October?.
*	8 ...	Apt., Vaucluse, France	7 lbs.	....	10 A.M.	Stone-fall; sp. gr. 3·48.
[f]	Nov. 13 ...	Edinburgh; London	=moon	E.S.E. to W.N.W.	2″ to 5″	blue; 23 miles high when first seen; $v.=8$ miles a second.
	13 ...	Dover; Hants	....	....	....	splendid meteor; brilliant.
	16 ...	Geneva	....	....	....	fireball.
	Dec. 13 ...	Ekatherineburg	....	....	....	ditto.
*	13 ...	Massing, Bavaria	3½ lbs.	....	11½ A.M.	Stone-fall; sp. gr. 3·26.
	16 ...	Schwartzenburg	....	....	....	fireball.
[g]1804.*	Mar. 17 ...	Berlin	large	W. to E.	....	ditto, followed by 2 detonations after bursting.
*	Apr. 5 ...	Possil, Glasgow	....	S.E. to N.W.	A.M.	Stone-fall; sp. gr. 3·53. Day-time.
	15 ...	Geneva	....	....	....	fireball.
	June 4 ...	Dessau	....	....	....	ditto.
	Aug. 19 ...	Eckwarden	....	....	....	ditto.
	July 29 ...	?	....	....	....	ditto.
	Sept. 7 ...	Tunbridge Wells	=moon	S.E. to N.W.	....	ditto; broke up and almost instantly vanished; 4 Sept.?
	10 ...	Weimar	....	....	....	fireball.
1805.	Feb. 1 ...	Saxony	....	....	....	ditto.
*	Mar. 25 ...	Irkutsk, Siberia	7+2¼ lbs.	....	5 P.M.	Stone-fall; two; sp. gr. 3·63. Doroninsk.

1805.*	June	Constantinople	....	....	day-time	Stone-fall; contains no iron ?; sp. gr. 3·17.
	July 21	London	....	....	....	fireball.
	Aug. 6	Berlin	....	....	streak 18″	ditto.
	Sept. 23	Weimar	....	....	....	ditto; 1806 ?.
	Oct. 14	Shrewsbury	large	....	....	great light; fell in the N.W. 1806 ?.
	21	Sweden	....	....	....	fireball.
	23	Germany	....	....	....	ditto.
*	Nov.	Asco, Corsica	....	....	....	Stone-fall; sp. gr. 3·66.
1806.	Feb. 11	Stockholm	=moon	....	....	fireball.
*	Mar. 15	Alais, France	8+4 lbs.	W. to E.	5 P.M.	Stone-fall; two; carbonaceous-like; sp. gr. 1·70.
*	May 17	Basingstoke, Hants	2½ lbs.	....	....	Stone-fall, after a detonating meteor.
	July 17	London; Edmonton	½ moon	S.E. to N.W.	....	fireball; very brilliant; conical; long tail.
?	Sept. 23	Weimar	....	....	....	aërolitic? (according to Baumhauer's Catalogue).
	28	?	....	....	....	bolide.
	Oct. 14	Swansea, &c.	....	....	....	lighted up a great extent of country. 1805 ?.
	Dec. 22	England	....	....	....	fireball.
1807.	Mar. 6	Geneva	....	....	....	ditto.
*	13	Timochin, Smolensk	160 lbs.	....	....	Stone-fall; sp. gr. 3·64; afternoon.
	Aug. 9	Nurenberg	....	....	....	fireball.
	Sept.	Fünen, Denmark	....	....	....	ditto. September 6 ?.
*	Dec. 14	Weston, Connecticut	300 lbs.	S.E. to N.W.	¼7 A.M.	Stone-fall; large explosive meteor; 3 miles per sec.
1808.*	Apr. 19	Parma, Italy	....	....	1 P.M.	Stone-fall; several; near Borgo.
	May 21	Ferentino	....	....	....	fireball.
*	22	Stannern, Moravia	....	....	6 or 10 A.M.	Stone-fall; 250 fell; no iron; sp. gr. 3·07.
	29	Cape Spartel	....	....	....	fireball.
	July 29	Troston	....	....	....	ditto. Boston ?.
	Aug. 15	Vienna, &c.	....	....	....	ditto.
*	Sept. 3	Lissa, Bohemia	....	....	3¼ P.M.	Stone-fall; 4 or 5 small stones fell.
	Nov. 11	England	....	....	....	fireball.

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[a] April 5, 1800 ?. N. America. Evidently confounded with that of Baton Rouge, 5th April, 1799. This meteor is said to have appeared as large as a house 70 feet square, at an apparent height of 200 feet; to have felt warm, and scorched vegetation near where it was supposed to have fallen.

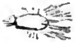
[b] 1802.? September 15. Loch Tay, Scotland. See Monthly Magazine for 1802.

[c] 1803. January 21. Between Barsdorf and Freiburg. Seemed to pass close to the ground; a whizzing noise heard, then it seemed to lie burning on the ground; next day a jelly-like mass found on the snow. Curious, if true.

[d] 1803.* May 9. Cambridge. During bright sunshine, a large oval meteor fell straight down to within 15° of the horizon; had a train of light and vapour: seen about same time at Swaffham in Norfolk, and in Lincolnshire at same hour; a shock, and loud noise and hissing sounds were heard; probably aërolitic.

[e] 1803.* July 4. Rather a curious account in Encyclopædia Britannica. More like an electric ball, and yet a vitrified stone found containing nickeliferous iron. A little doubtful perhaps if meteoric.

[f] 1803. November 13 (Nov. 6 ?). Said by some to have been as large as the August 18, 1773 meteor. Shaped like this:



[g] 1804.* March 17. Also at Newstrelitz.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1808.	Dec. 29 ...	Berne	....	....	....	fireball.
*	? ...	Hungary (Bohemia ?)	....	....	....	Stone-fall. Poggendorff, vol. iv. p. 451, 1854.
*	? ...	East Indies	....	....	....	ditto ditto.
	? ...	Greenland	....	N.W. to S.E.	....	ditto; said to be rare in the arctic region.
1809.	Apr. 9 ...	Tours, France	....	....	....	fireball.
	June 17 ...	St. Bart	....	....	....	ditto.
*	20 ...	Lat. 31° N., Long. 70½° W.	6 ozs.	....	....	Stone-fall; fell on ship-board (June 17 ?).
	July 29 ...	Neumark	....	....	....	fireball.
	Aug. 28 ...	Parma	....	....	....	ditto.
	Nov. 29 ...	Munich	....	....	....	ditto.
	Oct. 12 ...	London	....	....	....	fireball.
	? ...	Kikina, Smolensk	....	....	....	Stone-fall. Same as Mar. 1807, Timochin ?.
	Dec. 29 ...	Munich	....	....	....	fireball.
1810.	Jan. 2 ...	Geneva	....	....	....	fireball; or 3rd January.
?	Apr. 20 ...	Santa Rosas, New Grenada	1600 lbs.	....	....	Iron-fall ?; Arago and Buchner. Found or fell ?.
*	30 ...	Caswell, N. Carolina	3 lbs.+	....	2 P.M.	Stone-fall; several.
*	July 15 ...	Futteh-Ghur, Shahabad	....	....	....	Stone-fall; one large one. Middle of July. India.
*	Aug. 10 ...	Tipperary, Ireland	7¾ lbs.	....	11½ A.M.	Stone-fall; sp. gr. 3·67; at Moores-Fort.
*	Nov. 23 ...	Charsonville, France	40+20 lbs.	....	1½ P.M.	Stone-fall; three fell; near Orleans.
*	28 ...	Cerigo, Cape Matapan	....	....	9½ P.M.	aërolitic meteor.
	Dec. 30 ...	Greenland	....	....	....	fireball (29th December, 1808 ?).
1811.	Feb. 18 ...	Olmutz	....	....	....	ditto.
*	Mar. 12 ...	Poltawa, Russia	13 lbs.+	....	night	Stone-fall; two fell; sp. gr. 3·49. Kuleschofka.
	May 15 ...	Paris; Geneva	....	....	streak 10′	like a serpentine rocket; 77 miles high when first seen.
*	July 8 ...	Berlanguillas, Spain	....	....	8 P.M.	Stone-fall; 3 fell; sp. gr. 3·49. Near Burgos.
	July ...	Heidelberg	....	....	....	fireball; a gelatinous substance fell ?.
	Nov. 22 ...	New Orleans	....	....	....	ditto.
*	23 ...	Panganoor, India	....	....	....	Iron-fall ?. Contains iron and nickel.
1812.	Jan. 28 ...	Carlsruhe	....	....	....	fireball.
	30 ...	Louisville	....	....	....	ditto.
*	Apr. 10 ...	Grenade, Toulouse	....	N.E. to S.E.	8 P.M.	Stone-fall; sp. gr. 3·70; several fell.
*	15 ...	Erxleben, Saxony	4½ lbs.	....	4 P.M.	Stone-fall; sp. gr. 3·63; or 13th April.
*	Aug. 5 ...	Chantonnay, France	69 lbs.+	....	2 A.M.	Stone-fall; sp. gr. 3·46; three fell.
	23 ...	Utrecht	....	....	....	large bolide.
	Sept. 13 ...	Segovia	....	....	....	fireball.
	Nov. ...	Jamaica	large	....	....	ditto.
	15 ...	Carlsruhe and Vienna	....	....	....	ditto.
?	? ...	Hungary	....	....	....	Stone-fall ? (according to the Brit. Assoc. Reports).
[illegible]	[illegible]	[illegible]	....	....	....	fireball.

[e]1813.	Mar. 8 ...	Brünn	....	....	....	fireball; (aërolitic, according to Baumhauer's Cat.).
*	14 ...	Cutro, Calabria	....	....	....	Stone-fall and dust ?.
[f] *	21 ...	New Haven, Conn., U.S. ...	= moon	S.W. to N.E.	8″ or 10″	tail 12° long; detonation in 8′ after.
	Sept. 2 ...	Berne	....	....	....	fireball.
*	10 ...	Limerick	17+65+24 lbs.	E. to W.	9 A.M.	Stone-fall; sp. gr. 3·64; at Adare and Scagh. 6 A.M.?
*	Aug. or Sept.	Malpas, Cheshire	....	....	1 P.M.	stones fell. Ann. of Phil. 1813, vol. ii. p. 396.
	Oct. 20 ...	Swabia........................	....	....	....	fireball.
	Nov. 8 ...	Woodfort......................	....	....	....	ditto.
	10 ...	Sunderland	....	....	....	ditto.
*	Dec. 13 ...	Lontalax, Wiborg	....	....	....	Stone-fall; sp. gr. 3·07; Finland.
1814.	Jan. 27 ...	Augsburg; Zurich	large ?	....	....	fireball; also at Munich.
*	Feb. 3 ...	Bachmut, Russia..............	40 lbs.	....	....	Stone-fall; several; Government of Ekaterinosloff.
	Apr. 19 ...	Berlin	....	....	....	fireball.
*	July 3 ...	Canada........................	....	....	....	meteor; detonation; dust-fall; or 4th July ?.
	29 ...	Geneva	....	....	....	fireball.
	Aug. 3 ...	Frankfort......................	....	....	....	ditto.
*	Sept. 5 ...	Agen, France	18 lbs.+	....	....	Stone-fall; two fell at mid-day. Sp. gr. 3·60.
	8 ...	Augsburg......................	....	....	....	fireball.
	11 ...	Glasgow	....	towards S.	....	ditto; at right angles to the magnetic meridian.
	Oct. 14 ...	Germany	....	....	....	ditto; or 18th October.
[g] *	Nov. 5 ...	Doab, India....................	....	....	4½ P.M.	Stone-fall; 19 fragments picked up.
	9 ...	Moscow	....	....	....	fireball.
	Dec. 2 ...	Surrey; London	....	....	....	a great meteoric light; equal daylight.
1815.*	Feb. 18 ...	Loodianah, India	25 lbs.	....	noon	Stone-fall; near Durallah. In the British Museum.
	Apr. 30 ...	Florence	....	....	....	fireball.
	May 10 ...	Worcester	....	....	....	ditto.
*	14 ...	Malacca	= full moon	S.E. to N.W.	7½ P.M.	ditto; great detonation followed. 1849 ?.
	Sept. 16 ...	Göttingen	....	....	....	fireball.
	29 ...	London; S. England	brilliant	S. to N.	quick	ditto; burst.
[h] *	Oct. 3 ...	Chassigny, Langres...........	8 lbs.	....	8¼ P.M.	Stone-fall; sp. gr. 3·55; France.
1816.*	Aug. or July	Glastonbury	....	....	....	Stone-fall; Somerset.
	Jan. 8 ...	Pesth, Hungary	....	....	....	fireball.
*	Mar. 23 ...	Oxford; Surrey	....	S. to N.	11 P.M.	ditto; followed by a rumbling noise for 5′.
*	Aug. 7 ...	Hungary	....	....	....	ditto; at Nagy-Banya; burst with detonation.

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[a] 1808. December 29. Berne, Switzerland.

[b] 1810.? April 20. Santa Rosas, at Tocavita; said by some to have fallen in the night of that day; but this appears doubtful.

[c] 1810.* November 28. Fireball, evidently aërolitic: fell into the sea between Cape Matapan and the Island of Cerigo, Greece.

[d] 1812.? Hungary. According to Kesselmeyer, only the meteor of the 15th November.

[e] March 8, 1813. Brünn; only a fireball; perhaps same as that given as January 27th.

[f] March 21.* New Haven. Fragments kept falling off in parabolic curves to the earth.

[g] 1814.* November 5. Near Futtypore ?.

[h] 1815.* October 3. Contains scarcely any iron.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1816.	Aug. 13	Scotland	....	....	....	fireball.
	Oct. 19	Dusseldorf	....	....	....	ditto.
	Dec. 20	Hungary	....	....	....	ditto.
1817.	Mar. 2	Gothenburg	....	....	....	ditto.
	18	Lot-et-Garonne	....	....	....	ditto.
	Apr. 10	Bohemia	....	....	....	ditto.
	17	Rhine	....	....	....	ditto.
	27	Hesse	....	....	....	ditto.
	May 2	Göttingen	large	....	....	ditto; brilliant (or 3rd May). Fell into the Baltic ?.
	Aug. 7	Augsburg	....	....	....	ditto.
	Sept. 8	Richmond	....	....	....	ditto.
	Oct. 6	Tunbridge Wells	½ moon	....	....	white at first, blue, then red.
	17	Aix	....	....	....	fireball.
	Nov. 19	?	....	....	....	ditto.
	Dec. 8	England	....	....	....	ditto.
1818.	Jan. 18	Siberia	....	....	....	ditto.
	28	Campbelltown, Scotland	....	....	....	ditto.
a *	Feb. 6	Lincolnshire	large	N.W. to S.E.?	2 P.M.	equal semi-light; loud rumbling noise heard.
*	15	Limoges, France	....	....	....	Stone-fall; one large one ?.
	15	Toulouse	....	....	....	fireball (same as last ?).
	Mar. 2	Atlantic Ocean	....	....	....	ditto.
b *	April 10	Zaborzika, Volhynia	....	....	....	Stone-fall; sp. gr. 3·47. One stone.
*	June	Seres, Macedonia	15 lbs.	....	....	Stone-fall; sp. gr. 3·70.
	July 17	North America	....	....	....	fireball.
	Aug. 3	Worthing	....	....	....	ditto.
	5	Chelenfort	....	....	....	ditto.
*	10	Slobodka, Smolensk	7 lbs.	....	....	Stone-fall; sp. gr. 3·47. Russia.
	Sept. 5	Breteuil	....	....	....	fireball (or 6th instant).
	14	England	....	....	....	ditto.
	23	Kilkel	....	....	....	ditto.
c *	Oct. 31	Mehadia	....	....	....	aërolitic (Boguslawski's Catalogue).
	Nov. 13	Gosport	....	....	....	fireball.
	17	Gosport	....	....	....	ditto (same as last ?).
	Dec. 18	Halle	....	....	....	ditto.
	21	Fünen	....	....	....	ditto; or end of February ?.
1819.	Feb. 2	Canterbury	....	....	....	ditto.
	Mar. 26	Berne	....	....	....	ditto.
*	April	Salerno, Italy	....	....	....	Stone-fall (Poggendorff, 1854). At Massa-Lubrense.
	May 2	Aberdeen	....	....	....	fireball.

1819.		June	13 ...	Jonsac, France	6 lbs.	....	6 A.M.	Stone-fall; sp. gr. 3·08; contains no iron.
		July	24 ...	Youngstown ?	....	....	....	fireball.
		Aug.	1 ...	Tottenham, London	....	N.E. to S.W.	....	ditto.
			6 ...	Moravia	....	....	....	ditto.
	[d] *		13 ...	Amhurst, Mass., U. S.	....	....	8½ P.M.	a white silvery fireball; violent explosion.
			20 ...	Rotweil	....	....	....	fireball.
	*		? ...	Pulrose, Isle of Man	....	....	....	Stone-fall; light and scoriaceous; fell 1813–1819.
		Oct.	1 ...	England	....	....	....	fireball.
	*		13 ...	Politz, Gera, Prussia	7 lbs.+	....	8 A.M.	Stone-fall; three fell; sp. gr. 3·39; or 12th October.
			24 ...	Antwerp	....	....	....	fireball.
		Nov.	13 ...	St. Domingo	....	....	....	ditto.
			14 ...	Bohemia	....	....	....	ditto.
			18 ...	Tottenham	....	....	....	bolide.
			19 ...	Rochelle	....	....	....	ditto.
	[e] *		21 ...	Baltimore, Mass., U. S.	large	N.E. to S.W.	....	fireball; detonation heard 2′ after.
1820.?		Apr.	5 ...	in sea, near Antigua	....	....	....	aërolitic (according to Baumhauer's Catalogue).
			18 ...	Augsburg	....	....	....	fireball.
		May	10 ...	Andernach	....	....	....	ditto.
	*		21 ...	Oedenburg, Hungary	½ lb.	....	....	Stone-fall; smelt of sulphur.
	*	July	12 ...	Lixna, Dunaberg, Russia	40+14 lbs.	S. to N.	5½ P.M.	Stone-fall; several fell. Witepsk. June 30 ?.
			20 ...	Brünn	....	....	....	fireball.
	[f]	Aug.	6 ...	Ovelgönne, Finland	....	....	....	aërolitic (according to Baumhauer's Catalogue).
	*	Nov.	12 ...	Cholimschk, Russia	large	....	....	fireball, with detonation.
	[g] ?		29 ...	Cosenza; Ionian Isles	....	....	....	lighted everything up; like daylight. Calabria.
		Dec.	9 ...	Tumea	....	....	....	fireball.
			5 ...	Naples	....	....	....	ditto.
			30 ...	Zante	....	....	....	ditto.
1821.		Feb.	12 ...	Breslau	....	....	....	ditto.
	[h] ?	Mar.	5 ...	Pomerania	....	....	....	aërolitic fall (Boguslawski and Poggendorff).
			20 ...	St. Thomas's Island	....	....	....	large meteor.
		Apr.	28 ...	Leipzig	....	....	....	fireball.
		May	16 ...	Munich	....	....	....	ditto.
			17 ...	Germany	....	....	....	ditto; same as last ?.

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[a] February 6.* A hissing sound also said to have been heard.

[b] March 30.* O. S. according to Partsch.

[c] 1818.* October 31. Between Bucharest in Wallachia and Mehadia. A meteor by which the whole neighbourhood was lighted up for 5′. Brit. Assoc. Reports, 1849.

[d] August 13.* A gelatinous substance said to have been found.

[e] November 21.* Massachussets; Maryland, &c. Direction S. 44° W.; calculated diameter ½ mile.

[f] 1820. August 6. Ovelgönne; only a substance like pumice-stone, caused by a stroke of lightning falling into a hayrick.

[g] November 29.? Cosenza. Arago says a shower of stones; other accounts, only a great meteor. No mention of any detonations.

[h] March 5.? Pomerania. A doubtful fall; occurred during an earthquake, supposed to have been caused by the explosion of a meteor. Chladni thinks that the holes in the ground might have been caused by falling stones, which were not found because not searched for. (Gilbert's Ann., lxxi. 1822, p. 560).

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1821.	June 15 ...	Juvénas, Ardèche, France ...	220 lbs.+	....	3 P.M.	Stone-fall; 3 fell; sp.g. 3·10, contains 1·5 p.c. only of iron.
	21 ...	Mayo, Ireland	....	....	....	hailstones fell with a metallic interior. See Buchner.
	Aug. 20 ...	West Indies	....	....	....	fireball.
	30 ...	Dresden	....	....	....	ditto.
	Sept. 7 ...	at sea	....	E. to W.	....	glowing and red, like heated iron.
	8 ...	Bohemia	....	....	....	fireball.
	18 ...	at sea	= moon	W. to E.	....	oblique down from zenith; burst and fell into the sea.
	Oct. 7 ...	Saxony	....	....	....	fireball.
	30 ...	Marienwerder	....	....	....	ditto.
	Nov. 28 ...	Naples	....	....	....	ditto.
	30 ...	Delitzsch	....	....	....	ditto.
	Dec. 1 or 2...	Leipzig; Saxony	....	....	....	ditto; two?.
	3 ...	Weimar	....	....	....	ditto.
	4 ...	Görlitz	....	....	....	ditto.
	11 ...	England	....	....	....	ditto.
	21 ...	Naples	....	....	....	ditto.
*	24 ...	Bromberg; Wirtemberg ...	large	E. to W.	6 P.M.	ditto; accompanied with detonation.
	25 or 26 ...	Lausitz; Weimar?	....	....	....	fireball; two?.
	28 ...	Augsburg	....	....	....	ditto.
1822.	Jan. 11 ...	Cherbourg	....	....	....	ditto.
	14 ...	Eichesfelt	....	....	....	ditto.
	25 ...	Prussia	....	....	....	ditto.
	Feb. 6 or 7...	Moravia and Bavaria?	....	....	....	ditto; two?.
	8 ...	Neuhausen	....	....	....	ditto.
	9 ...	Leipzig	....	....	....	ditto; same as last?.
	Mar. 1 ...	Brunn	....	....	....	ditto.
	9 ...	N. America	....	....	....	ditto (= next?).
*	16 ...	Richmond, Virginia	....	N.E. to S.W.	....	vast luminous meteor, burst with loud explosion.
	31 ...	Leipzig	....	....	....	fireball.
	Apr. 9 ...	Rhodes	....	....	....	long bright column of meteoric light, exploding with [many sparks.
*	June 3 ...	Angers, France	30 ozs.	....	8 P.M.	a small explosive meteor and stone-fall.
	9 ...	Moravia	....	....	....	fireball.
	13 ...	Christiania, Norway	....	....	....	ditto; a bituminous substance fell?.
*	16 ...	Cherbourg	....	....	....	a luminous meteor and explosion.
	17 ...	Leipzig	....	....	....	fireball.
?	17 ...	Catania	....	....	....	detonating meteor?.
	July 19 ...	Hamburgh	....	....	....	fireball.
	28 ...	Brunn	....	....	....	ditto.
	Aug. 6 ...	Paris; Caen; Southampton	large	....	streak 5′	serpentine trail of great size. Also seen at Havre.

1822.*	Aug.	7	Kadonah, Agra	....	....	....	Stone-fall; night.
		7	Moravia	....	....	....	fireball.
[b] ?		11	Liège; Coblentz	....	....	....	large mass of fire fell down with a great explosion; possibly electrical.
		11 or 12	Alps	....	....	streak 3′	most brilliant meteor; cast shadows.
		16	Rochelle, France	....	S.E. to N.W.	....	serpentine course; 66 leagues high; also seen at Paris.
		22	Bromberg	....	....	....	fireball.
		23	Posen	....	....	....	ditto.
*	Sept.	1	Fort Royal	large	W. to E.	quick	train visible several minutes; great detonation.
*		10	Carlstadt, Sweden	....	....	11½ P.M.	Stone-fall; several ?.
*		13	La Baffe, Epinal, France	sp. gr. 3·66	....	7 A.M.	ditto; one stone about 3 inches in diameter, containing nickel and chrome.
	Oct.	13	Orenburg	....	....	....	fireball.
		27	Berleburg	....	....	....	ditto.
		28	Brighton; S. England	½ moon	....	....	fine meteor (22nd October ?).
	Nov.	4	Chili; S. America	large	....	....	ditto ditto.
		11	Freiberg	....	....	....	fireball.
		12	Potsdam	....	....	....	ditto.
		15	Apenrade	....	....	....	ditto.
		19	Valparaiso	⅔ moon	....	2 A.M.	ditto; train of fire; jerked and burst.
[c] *		30	Futtehpore, Doab, India	22 lbs. +	S.E. to N.W.	evening before sunset.	Stone-fall; several; sp. gr. 3·52. Umballah ?.
	Dec.	21	Brünn	....	....	....	fireball.
1823.	Jan.	11	Augsburg	....	....	....	ditto.
		24	England	....	....	....	ditto.
		26	Gosport	....	....	....	ditto; perhaps same as last ?.
	Apr.	2	Manheim	....	....	....	ditto.
		6	Berlin	....	....	....	ditto.
		9	Potsdam	....	....	....	ditto.
	May	2	Embleton	....	....	....	ditto.
		20	Ragusa	....	....	....	ditto.
		23	Kiel; Denmark	....	....	....	ditto.
	July	30	Leipzig	....	....	....	ditto.
*	Aug.	7	Nobleboro', Maine, U. S.	16 lbs.	....	4½ P.M.	Stone-fall; two fell; sp. gr. 3·09.
		9	Singen	....	N.E. to S.W.	....	fireball.
		12	Tübingen	....	....	....	ditto.
		19	Munich	....	....	....	ditto.
		20	Ragusa	....	....	....	ditto.
	Oct.	3	Königsberg	....	....	....	ditto.
	Nov.	9	Prague	....	....	streak 2′	ditto (or 8th November ?).

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[a] June 15.* Juvénas. June 21 ?.

[b] August 11 or 12. Alps; perhaps another account of the last.

[c] November 30.* Doab. The same meteor was seen at a distance of 300 miles from where the stone fell: Rourpore, 75 miles N.E. from Allahabad, is also given as the locality of this fall: it seems probable that two stones fell, and which have been preserved, at some distance from each other. See Reports of the Sittings of the Imperial Academy of Sciences of Vienna, and a recent paper by Haidinger on this stone-fall, as well as on that of Shalka, Pegu, Assam, and Segowlee.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1823.	Nov. 27 ...	Naples ?	....	....	....	fireball.
	Dec. 6 ...	Aix	....	....	....	ditto.
	13 ...	Belley, France	....	....	....	ditto. Département de l'Ain. [at Cento.
[a]1824. *	Jan. 15 ...	Renazzo, Bologna, Italy	12 lbs.+	....	9 P.M.	Stone-fall; three fragments fell; sp. gr. 3·25. Also
	Feb. 3 ...	Görlitz	....	....	....	fireball.
[b] *	18 ...	Irkutsk, Siberia	5 lbs.	....	noon	Stone-fall; near Tounkin. 7 A.M.?. May 14 ?.
	Mar. 1 ...	Berlin	....	....	....	fireball.
	April 17 ...	Linlithgowshire	....	N. to S.	quick	brilliant meteor. At Borrowstowness.
	June 9 ...	Leipzig	....	....	....	fireball.
	Aug. 12 ...	Tuscany	....	....	....	ditto; or 11th August.
?	23 ...	Mendosa, S. America	....	....	....	ditto; and meteoric dust fell ?. Poggendorff.
	Sept. 13 ...	Petersburg	....	....	....	small bluish globe of fire; day-time.
*	Oct. 14 ...	Zebrak, Beraun	4 lbs.	....	8 A.M.	Stone-fall; sp. gr. 3·60. In Bohemia.
	20 ...	Sterlitamak, Russia	....	....	....	hailstones containing iron pyrites fell! meteoric ?.
	Nov. 14 ...	Mainz	....	....	....	fireball; or 13th November.
	16 ...	Bonn	....	....	....	fireball.
	27 ...	Erlangen; Prague	= moon	S.E. to N.W.	4″ or 5″	ditto.
	Dec. 10 ...	Mans, France	....	....	....	ditto.
	15 ...	Magdeburg	....	....	....	ditto. [substance fell after a fireball ?.
	17 ...	Neuhaus, Bohemia	....	....	....	aërolitic (Boguslawski's Catalogue). A resinous
1825.	Jan. 2 ...	Arezzo	....	W. to E.	quick 5″	fireball; tailed; horizontal; brilliant. 2 A.M.
*	16 ...	Oriang, India	....	....	evening	Stone-fall; in Malwate. Several hot stones.
	17 ...	Bromberg	....	....	....	fireball.
	24 ...	Königsberg	....	....	....	ditto.
	Feb. 3 ...	Nurenburg	....	....	....	ditto.
	4 ...	Cassell	....	....	....	ditto.
*	10 ...	Nanjemoy, Maryland, U.S.	16 lbs.	N.W. to S.E.	....	Stone-fall; sp. gr. 3·66; about noon.
	June 28 ...	Frankfort; Stutgardt	....	....	....	fireball. July 28 ?.
[c] ?	July 5 ...	Torrecillas dal Campo, Spain.	1 oz. to 1 lb.	....	2 P.M.	stones fell; perhaps hailstones.
[d] ?	28 ...	Cherson, Russia	....	....	....	aërolitic (according to Baumhauer's Catalogue).
	Aug. 3 ...	Meidling	....	....	....	fireball.
	22 ...	Utrecht	....	....	....	fireball; seen all over Holland.
	Sept. 10 ...	Liancourt, France	¾ moon	N.E. to S.W.	....	fireball; oval and tailed.
*	15 or 14	Owhyhee, Sandwich Islands	30 lbs.	....	A.M.	Stone-fall; 2 fragments; sp. gr. 3·39; September 27 ?
	20 ...	Hanover	....	....	....	fireball.
	24 ...	Leipzig	....	....	....	ditto.
	Oct. 17 ...	Prague	....	....	....	ditto.
	19 ...	Berlin	....	....	....	ditto.
	22 ...	[illegible]	....	....	....	ditto.

[e] 1825.	Nov.	...	Ohio, U. S.	>moon	E. to W.	quick	burst partially.
[f]		3 ...	Calcutta	⅓ moon	E. to W.	5″ or 6″	horizontal motion; seen by twilight.
		4 ...	Halle	....	....	....	fireball.
		5 ...	Merseberg	....	....	....	ditto. Probably same as the last.
		9 ...	Pils	....	....	....	ditto.
		14 ...	Leith	....	E. to W.	streak 2′	quick motion; large, long tail.
		22 ...	Calcutta	....	E. to W.	streak 2¼′	fireball, with large comet-like tail.
	Dec.	1 ...	Berlin	=moon	....	....	reddish; no streak.
		2 ...	Calcutta	large	....	streak 5′	globular.
		10 ...	Halle	....	....	....	fireball.
		18 ...	Frankfort-on-Maine	....	....	....	ditto.
[g] ?	May	12 ...	Bayden, Wiltshire	....	....	....	Iron-fall ? (Poggendorff, viii. 1826).
1826.?		? ...	Georgia, U. S.	....	....	....	stones fell ?, and killed several people. See Athenæum, [1836, p. 803.
	Feb.	14 ...	La Manche	....	....	....	fireball.
*		15 ...	Lugano, Italy	....	....	....	ditto; followed by loud detonation. No stones found.
?	Apr.	1 ...	Saarbrücken	....	downwards	....	a curious meteoric appearance and noise.
		14 ...	Glasgow	....	....	....	fireball.
[h] *	May	12 ...	Gloucestershire	⅓ moon	....	....	bluish; vanished, leaving a red spark.
[i]		19 ...	Ekaterinosloff	86 lbs.	....	....	Stone-fall; sp. gr. 3·77. (1825 ?.)
	July	21 ...	Heidelberg	....	....	....	fireball.
		29 ...	Florida........................	....	....	....	ditto.
	Aug.	3 ...	Frankenstein	....	S.W. to N.E.	....	ditto.
		3 ...	Leipzig	....	E.N.E. to W.S.W.	....	ditto.
		8 ...	Odensee	....	....	....	ditto.
		11 ...	Halle	....	....	....	ditto.
		18 ...	England	large	....	....	a fine meteor.
		26 or 27	Edinburgh	....	S.W. to N.E.	quick	fireball; like a rocket; 45° arc; train; burst.
[j] *	Aug.	...	Lot-et-Garonne, France	....	....	....	aërolitic (according to Baumhauer's Catalogue).

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[a] 1824.* January 15. Renazzo. Some authorities give February 6, at Arenazzo; others January 13.

[b] February 18.* Tounkin, near Irkutsk: according to some accounts, fell May 14.

[c] July 5.? Torrecillas dal Campo, Spain; an abundant shower of stones; men and cattle suffered much. Gazette de Madrid, July 18, 1825. Ann. de Chimie, vol. xxx. p. 422, 1825.

[d] July 28.? Cherson. Some stones fell, one 7 lbs. Doubtful according to Chladni.

[e] November.? Ohio ?. Part of the interior of the nucleus seemed to separate from the rest and fall to the earth, breaking into a number of small balls, without noise.

[f] November 3.? Calcutta (1826 ?).

[g] May 12.? Bayden, Wilts; according to P. A. Kesselmeyer, of Frankfort, the piece of iron which fell is in possession of Mr. Schwickard in Mexico, who bought it from a mineral dealer in London. Prof. Nöggerath, of Bonn, is said to have seen it; it looked like meteoric iron, and the magnetic needle was greatly affected by it. Possibly the same as the large meteor seen in Gloucestershire, May 12, 1826.

[h] 1825.* May 12. Aërolitic, according to Baumhauer's Catalogue; probably only a large meteor; seen also in Wiltshire, according to Baumhauer.

[i] May 19.* The principal mass in the museum at Odessa.

[j] August.* Lot-et-Garonne (one account says Castres in Gironde); a large stone fell, according to Quetelet, during a thunder-storm, on Mount Galapian.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
[a]1826.*	Sept. ...	Waterville, Maine, U. S.	⅓ moon	....	....	fireball; large and brilliant; burst with great noise at night.
	4 ...	Halle	....	....	....	fireball.
	13 ...	Bordeaux	....	....	5 A.M.	ditto; daybreak; brilliant; train of fire.
	Nov. 3 ...	Calcutta	⅔ moon	S.E. to N.W.	....	dissipated into sparks. 1825 ?.
	Dec. 31 ...	Dammerung	....	....	....	fireball; in Lippéschen.
[b]1827.*	Feb. 27 ...	Ghazeepore, India	several lbs.	....	3 P.M.	Stone-fall; *one* fragment; sp. gr. 3·5.
[c] *	May 9 ...	Nashville, Tennessee	5 lbs.+11 lbs.	W. to E.	4 P.M.	Stone-fall; three fragments; sp. gr. 3·55. Drake's Creek.
	Aug. ...	Greenwich	large	....	....	fireball, increased from a point to 7 times larger than Jupiter.
[d] ?	30 ...	Kuld-Schu	....	....	....	aërolitic (according to Baumhauer).
*	Oct. 5 ...	Bialistock, Russian Poland	4 lbs.	....	9½ A.M.	Stone-fall; contains no iron; sp. gr. 3·17. (Oct. 8 ?.)
	Nov. 6 or 7	Teneriffe	....	....	....	fireball.
	15 ...	Frankfort	....	....	....	ditto.
[e]1827 or 28.?	Aug. or Sept.	Allport, Derbyshire	sp. gr. 2·0	....	3 P.M.	a meteoric light traversed the sky, and an explosion.
1827.*	Aug. ...	China	....	....	....	Stone-fall; in Boguslawski's 10th Supp. to Chladni.
1828.	Jan. 18 ...	Gotha	....	....	....	fireball.
	Feb. 11 ...	New York	....	S.W. to N.E.	20° in 2″	fine grass-green; scintillations given off.
*	May ...	Tscheroï, Turkey	....	....	....	Stone-fall (Pogg., 1835, vol. xxxiv. p. 341).
*	June 4 ...	Richmond, Virginia	4 lbs.	....	9 A.M.	Stone-fall; sp. gr. 3·47.
	Sept. 7 ...	Horton, Ribblesdale	=moon's *d.*	⊥ towards E.	15° in 3½″	equal sunlight; increased from a 1st* to 30′ in diameter.
	Oct. 10 ...	Turin	....	....	....	fireball.
	Nov. 6 ...	Cape Town, S. Africa	....	....	....	a fine meteor.
	11 ...	Sury, Département de Loire	large	....	....	seen during sunshine; or 12th November.
1829.*	May 8 ...	Forsyth, Georgia, U. S.	36 lbs.	....	3½ P.M.	Stone-fall; sp. gr. 3·50.
?	July ...	N. America	....	....	....	Stone-fall ?. An Indian killed. Athen^m, 1836, p. 803.
[f]	Sept. 26 ...	Dusseldorf	....	....	....	aërolitic (according to Baumhauer's Catalogue).
*	29 ...	Krasnoi-Ugol, Russia	....	....	2 P.M.	Stone-fall. 7 stones fell. Government of Käsan (Rjäsan).
	Aug. 14 ...	Gümbinnen	....	....	....	three fireballs.
*	15 ...	Deal, New Jersey, U. S.	....	....	night	Stone-fall.
	26 ...	Parina	....	....	....	bolide.
*	Oct. 19 ...	Cape Town, S. Africa	large	....	10 P.M.	great light and brilliant; detonation 2′·45 afterwards.
[g] ?	Nov. 19 ...	Prague	....	....	....	aërolitic (according to Baumhauer's Catalogue).
1830.	Feb. 15 ...	Edgbaston, Birmingham	=moon	N.E. to S.W.	about 7½ P.M.	twice appeared and disappeared at intervals of 2″. Streak visible for some time.
[h] *		Launton, Oxfordshire	2½ lbs.	N.E. to S.W.	7½ P.M.	Stone-fall, with noise and light; sp. gr. 3·625.
	Oct. 10 ...	Krusenstern ?	....	....	....	fireball.
	Dec. 14 ...	Warsaw	....	....	....	ditto.
	Mar. 14 ...	Freiberg; Wirtemberg; Baden	=moon	S. to N.	2″	ditto.
1831.	Jan. 12 ...	Berlin	large	....	....	ditto; =moonlight; burst like a rocket.
	28 ...	Gotha	....	....	....	ditto.

1831.	Jan. [illegible] ...	Breslau	....	....	....	fireball.
?	July 18 ...	Foligno, Italy	....	....	....	a meteoric detonation in the air ?. Tuscany.
*	18 ...	Poitiers, France	40 lbs.	....	....	Stone-fall; sp. gr. 3·55. May 13 ?.
*	Sept. 9 ...	Wessely, Moravia	6¼ lbs.	....	3½ P.M.	Stone-fall. At Znorrow.
	Oct. 20 ...	Hopsigheim ; Wirtemberg ...	= moon	N.W. to S.E.	3 A.M.	fireball ; gave out sparks ; a hissing sound heard ?.
	Nov. 13 ...	Brüneck	....	....	....	ditto.
	13 ...	N. of Spain	large	E. to W.	streak 6′	left a broad track of light 15″ wide, visible for 6′.
	26 ...	Sogel	....	....	....	fireball.
	29 ...	Hildburghausen	= moon	....	....	rose in the west.
	Dec. 8 ...	Herefordshire	large	....	....	by daylight ; also seen at Bath.
[i]	Dec. ...	Moravia	6¾ lbs.	....	....	aërolitic (according to Kämtz and Baumhauer's Cat.).
[j]1832.	Jan. 2 ...	Bordeaux.........	large	N.E. to S.W.	rapid	like a 24-pounder ball ; brilliant, greenish.
	23 ...	Zurich	....	....	....	fireball.
	Feb. 7 ...	Lauenberg	....	....	....	ditto.
*	March 7 ...	Cutro, Calabria	large	....	streak 5′	ditto ; with loud detonation.
	15 ...	Berlin	....	W. to E.	....	ditto. [tion.
	Apr. 11 ...	Tirkut, India	large	W. to E.	5″	moved horizontally ; burst like a rocket ; small eleva-
	May 20 ...	Bengal, India	....	N. to S.	3″	pear-shaped; did not burst; green and blue; long train.
	31 ...	Riga.........	....	....	....	fireball.
	June 23 ...	Delhi, India.........	large, ⅔ moon	E.S.E. to N.N.W.	115° arc	formed as if by three balls uniting into one.
[k]	29 ...	Plymouth ; Brest	= moon	N. to S.	10″	had a long tail and rather tremulous motion ; bluish.
	July 24 ...	Meerut, India	large	....	....	dazzling.
	Oct. 6 ...	Berlin	....	....	....	fireball.
	12 or 13	Cologne	large	N. to W.	....	like a rocket, or large comet.
	13 ...	Ulm	....	....	....	fireball.
	14 ...	Tyrol	....	....	streak 15′	a meteoric luminous appearance.
[l]	24 ...	Grünewald	....	....	....	fireball.

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[a] September.* Waterville. The *stone* said to have been picked up ; probably not really meteoric.

[b] February 27.* At Mhow, near Ghazeepore.

[c] May 9.* Drake Creek, Nashville, in Summer co., U. S. May 22 ?.

[d] August 30.? (May 22 ?) A doubtful stone-fall ; from a newspaper ; also Kämtz, iii. 296.

[e] August or September, 1827 or 1828.? Allport, Derbyshire. The meteorite picked up, supposed to have fallen on this occasion, now in Dr. R. A. Smith's possession, of Manchester, appears to Mr. Greg to be a more than doubtful substance ; more like a kind of compact charcoal, with particles of sulphur and iron pyrites imbedded ; nevertheless peculiar : pieces are stated to have fallen after the explosion occurred.

[f] 1829. September 26. Only a fireball. Kämtz, vol. iii.

[g] 1829.? Prague. Doubtful ; little pieces of stone with a red crystalline surface, that smelt of phosphorus and sulphur. Kämtz, iii. 297, and Pogg. Annalen. Does not state if from a fireball.

[h] 1830.* February 15. Launton, near Bicester. This stone is in the possession of Dr. Lee, F.R.A.S. See Buck's Gazette, April 10, 1830.

[i] December. Moravia. On the authority of a Vienna newspaper ; merely a confused account of the fall of September 9 previously.

[j] 1832. January 2. Bordeaux, according to Baumhauer's Catalogue.

[k] June 29. Plymouth. Increased in size from a bright star in the zenith to that of the full moon ; went seawards, still increasing in size till lost to sight ; no noise ; white, blue, red.

[l] November 14. Tyrol. 6 A.M. A streak of light appeared downwards, became a long bright tail in an undulatory state, then a misty cloud formed which remained stationary for 15′. The light at one time so intense, that the smallest type could be read. Meteoric ?.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1832.	Oct. 19	England	....	....	....	fireball.
	Dec. 13	Herefordshire	large	E. to W.	....	large globe of fire; cast shadows; brilliant.
[a]	19	England	....	....	....	aërolitic (according to Baumhauer's Catalogue).
	20	Bonn	....	....	....	fireball.
[b] or 1833.		W. of Umballah, India	....	....	....	Stone-fall (Brit. Assoc. Reports).
[c]1833.*	Mar. 18	Madras	....	towards N.W.?	2″ or 3″	detonation 6½′ after bursting. 5½ P.M.
	Apr. 19	Nurenberg, Prague	....	....	....	fireball.
	May 20	Chichester	....	....	....	ditto.
[d] ?	July 16	Nachratschinsk, Tobolsk	....	....	3½ P.M.	aërolitic (according to Baumhauer's Catalogue).
	Aug. 10	Worcestershire	....	....	....	fireball.
[e]	Sept.	Islay, Scotland	=moon	E. to W.	very slow	ditto; no streak or tail; 180° arc; did not burst.
	Oct. 2	Hildburghausen; Wirtemberg	....	S.W. to N.E.?	....	fireball; brilliant.
	Nov. 12	Germany	....	....	....	ditto.
	12 or 13	United States	⅔ moon	....	....	seen during the celebrated shower of meteors.
[f] *	20	Presburg	....	....	....	fireball, and detonation.
[g] *	25	Blansko, Moravia	8lbs.+	....	6½ P.M.	Stone-fall; meteor and detonations. Three stones fell.
[h] *	end of Nov.	Kandahar; Affghanistan	....	....	....	Stone-fall; one of 3 seers weight; a person killed in a
	Dec. 12	Frankfort	....	....	....	large fireball; or 13th Dec. [court-yard.
	11	Herefordshire	....	....	....	large and dazzling fireball; globular; greenish-blue.
	12	at sea	....	....	....	fine meteor.
*	28	Volhynia, Russia	30 lbs.	....	....	Stone-fall; or 27th December. At Okaninak.
[i]1834.	Jan. 2	Zeitz, Saxony	....	....	....	aerolitic? (Baumhauer's Catalogue).
	30	Gainsborough	....	E. to W.	....	fireball.
	Feb. 4	Upper Silesia	=moon	....	....	high up in sky. At Cracow chiefly.
*	Mar. 10	Hirschberg, Silesia	....	....	3½ A.M.	a brilliant meteor; exploded like thunder.
	May 15	Bunzlau	....	....	....	a fine meteor. [nith to the horizon. 8 P.M.
	June 7	Philadelphia, U. S.	....	towards S.W.	10′	a brilliant white meteoric light reaching from the ze-
*	12	Charwallas, Hissar, India	7 lbs.	....	8 A.M.	Stone-fall; or June 8th. Sp. gr. 3·38.
	July 4	S. Herefordshire	6 > Venus	⊥ down	slow	divided into 3 balls; reddish; left a streak during twi-
	Aug. 10	Brussels	....	....	....	fireball. [light.
	Sept. 29	S. Herefordshire	....	....	streak 2½′	a bright meteoric light; cast shadows; by twilight.
	Oct. 2	Cologne	> Jupiter	horizontal	2″	divided into two parts; dazzling.
	Nov. 13	N. America	....	....	....	fireball; same as November 13, 1835?.
[j] ?	29?	Raffaten, Hungary	....	....	....	Stone-fall; or 13th Nov. (Brit. Assoc. Reports).
	30	Naples?	....	....	....	fireball.
*	Dec. 15	Marsala, Sicily	15 lbs.?	....	night	Stone-fall; or 10th Dec. Many (Thom. Met. p. 327).
*	17	Neuhaus, Bohemia	....	....	....	aërolitic (Boguslawski's Catalogue).
?	?	Szala, Hungary	....	....	....	Stone-fall? = Raffaten? = Platten-See?.
1835.	Jan. 12	Breslau	....	....	....	fireball.

1835.		Jan. 13	Berlin	....	W. to E.	....	small fireball, seen by strong moonlight.
k	*	18	Löbau	....	....	4½ P.M.	Stone-fall; no detonation heard.
l	?	23	Quito	....	....	....	meteor; and noises like firing of cannon for some time.
		Feb. 6	Parma	large	....	....	fireball.
m	?	Mar. 22	Prussian and Russian frontier	....	....	9 P.M.	a remarkable meteoric appearance and noise.
		June 13	Königsberg	....	W. to E.	....	a reddish fireball.
		23	New Grenada	....	....	....	fireball (January 23?).
n	*	July 17	Milan; Wirtemberg	....	S.E. to N.W.	8½ P.M.	like a cannon-ball; long train; detonation.
		18	Aarhus; Berlin	....	E. to W.	....	tail divided into several balls.
o	*	30	Dickson co., Tennessee, U.S.	9 lbs.	W. to E.?	2½ P.M.?	Iron-fall (or July 31 or August 1?).
p		Aug. 4	S. Herefordshire	....	....	....	a great concussion in the air high up.
	*	4	Cirencester	2 lbs.	W. to E.	4½ P.M.	Stone-fall; sp. gr. 3·4.
q		Sept. 6	Gotha	....	....	....	shooting-star; fell leaving a jelly-like mass on the ground.
		18	at sea (Scotland?)	....	S.W. to N.E.	....	pear-shaped; blue; tailed; sparks.
r	*	Nov. 13	De l'Ain, France	large	S.W. to N.E.	9 P.M.	incandescent; trail; cast shadows; loud detonation.
		13	N. America	....	....	....	fireball (same as November 13th, 1834?).
		17	St. Louis, U. S.	....	....	....	fireball.
		Dec. 12	Berlin and Magdeburg	large	....	2′	no noise; about midnight; or 13th December.

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[a] **1832. December 19. England; only a fireball, according to Kämtz and** Pogg. Annalen.

[b] 1832 or 1833. India; between the Punjab **and River Jumna. Same as** Nov. 30, 1822, at Futtehpore.

[c] March 18.* Madras. One account says it **disappeared without bursting at** 35° elevation.

[d] 1833.? July 16. Tobolsk. Hail fell; and **it is said stones of an angular** form. Doubtful.

[e] 1833. September. Islay. About 1833 or 1834; private notice; **light** as full moon; visible more than a minute: possibly the one described by **Dr.** Trail, September 18, 1835.

[f] November 20. Presburg. A fall of *stones* this year near Presburg; **see** Brit. Assoc. Reports; but probably the fall at Blansko, November 25: **possibly** the meteor of the 20th November.

[g] November 25.* Blansko, Moravia. One loud detonation, like a report of a cannon, followed by the rattle of musketry: according to Reichenbach, 8 stones or fragments were found.

[h] End of November.* Kandahar. According to Arago, end of April 1834.

[i] 1834. January 2 (or 1st); a mere newspaper humbug; according to Chladni, a piece of granite.

[j] 1834.? November 29.? Raffaten, borders of Hungary and Wallachia. More precise information of this fall is wanting, as well as for the locality: it may be the Szala fall, or the Moravian fall of 25 November, 1833; possibly **Raffaten is intended for Lake Balaton, another name for the Platten-See.**

[k] **1835.* January 18. Löbau. Several small friable vesicular pieces from** size of a pea to that of a walnut; for a curious account of this, see Boguslawski's 10th Supplement of Chladni, in Pogg., p. 353. Vol. iv. 1854.

[l] January 23.? Quito, Carthagena, &c. Noises heard apparently in the air from 1 A.M. till 8 A.M. Difficult to explain; possibly subterranean noises.

[m] March 22.? Fortress of Troizkosaffsk. See Boguslawski's Catalogue.

[n] July 17.* White; brilliant; sparks and train of light; exploded with noise like a cannon over Wirtemburg; also seen at Stutgardt, Heilbronne, and many other places.

[o] July 30.* Dickson co., Tenn. Loud detonation; fell into a cotton field; mass only found on ploughing up the land.

[p] August 4.* Herefordshire; probably the bursting of the meteor, from which proceeded the stone picked up same day at Aldsworth, 13 miles from Cirencester; cloudy at the time; possibly thunder.

[q] September 6. Gotha. Fell 3 feet from the observer on the ground with a loud noise. Pogg. Ann., vol. xxxvi. p. 315.

[r] November 13.* Simonod, near Belley, de l'Ain, France. This meteor is said to have set fire to a barn; perhaps electrical, or possibly an optical deception and coincidence; a stone, resembling obsidian, was found containing some arsenic and iron but no nickel, and is not meteoric, according to **Reichenbach; sp. gr.=1·35.**

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1836. *	Feb. 8 ...	Rivoli, Piedmont	....	....	7 A.M.	large meteor and detonation.
[a] *	Jan. 12 ...	Cherbourg	⅔ moon	....	6½ P.M.	cast shadows; detonation heard at Coutances.
	Apr. 24 ...	Rossano, Calabria	large	....	....	like a wooden beam on fire.
	June 10 ...	Sury, Département de Loire	> Venus	S. to N.	....	brilliant; did not burst; white before and reddish tail.
*	Aug. 20 ...	Illinois, U. S.	large	....	streak 15′	during sunshine; explosion and noise; 4 P.M.
	Sept. 18 ...	Florence	....	....	10 A.M.	fireball. A doubtful substance found? electrical?.
	Oct. 18 ...	Breslau	large	....	....	short tail; no noise.
[b]	Nov. 5 ...	Havre, Southampton	large as moon	straight down	slow	pale; 3rd or 6th of November; seen at sea.
?	22 ...	Silesia	....	....	....	atmospheric explosion. [stones from 1 lb. to 80 lb.
*	Dec. 11 ...	Macao, Brazil	sp. gr. 3·72	5 A.M. or	11½ P.M.	large meteor; burst with noise; very large shower of
?	? ...	Platten-See, Hungary.........	....	....	....	Stone-fall (Brit. Assoc. Reports); =Szala, 1834?.
[c]1837. *	Jan. 5 ...	Vesoul; Toulouse	=⅔ moon	N.N.E. to S.S.W.	3″; slow	tailed; light as day; detonated loudly; 1¼ A.M.
*	15 ...	Mikolowa, Hungary	....	....	5 P.M.	Stone-fall (Poggendorff).
[d] ?	Apr. 15 ...	Austria............................	6 ozs.	....	....	Stone-fall. See Thomson's Meteorology.
[e] *	May 5 ...	East Bridgewater	¼ lb.+	....	3½ P.M.	meteor and fall of nine small *stones*; sp. gr. 2·16.
*	July 21 ...	Gross-Divina, Hungary	19 lbs.	....	noon	Stone-fall; sp. gr. 3·55.
[f]	Aug. 5 ...	Newhaven, U. S................	large	S.W. to N.W.	1′	equal sun-light; like molten iron.
	29 ...	Upper Silesia	....	....	slow	with reddish tail.
[g]	30 ...	Cork, S. Ireland	> moon	S.S.W. to N.N.E.	quick	oval; bluish; burst into red stars.
*	Aug. ...	Esnaude, Charente	3 lbs.	....	....	Stone-fall. France.
	Sept. 21 ...	Aigle; Paris......................	large	....	6½″	cast shadows. Dauphine.
	Nov. 1 ...	Milan	....	....	....	fireball.
	Dec. 14 ...	Connecticut, U. S.	> Venus	....	1″ to 5″	streak 10″ visible; seen over the whole state.
	30 ...	Trebnitz	....	N. to S.	....	by day-light; bright silver-white; sparks after.
1838.	Jan. 2 ...	Breslau	large	N.E. to S.W.	streak 2′	cast shadows; blue, red.
[h]	Mar. 17 ...	Kensington, London	5′ *diam.*	N.W. to N.E.?	30° in 1½″	large bolide; brilliant; streak 10′; tailed.
*	Apr. 18 ...	Akburpoor, India	4 lbs.	....	....	Stone-fall; near Cawnpore.
	May 18 ...	Michigan, New York	....	....	....	brilliant meteor; burst; also seen in Canada.
*	June 6 ...	Chandakapore, Berar, India	....	....	....	Stone-fall; 3 fragments; sp. gr. 3·53.
[i]	Aug. 9 ...	Germany	....	....	streak 10″	fine meteor; or August 10.
*	Oct. 13 ...	Cape of Good Hope	many	N.W. to S.E.	9½ A.M.	Stone-fall; carbonaceous-like; at Bokkewelde.
	Nov. 13 ...	Cherbourg	large	horizontal	quick	fireball.
	16 ...	Condé-sur-Noir	....	....	....	a fine meteor.
	? ...	Palmacottah; S. India	=moon	....	streak 20′	gradually paled and faded away.
1839.	Jan. 6 ...	Milan	....	....	....	fireball.
	12 ...	Parma	....	....	....	ditto.
	Feb. 6 ...	ditto................................	....	....	....	ditto.
*	13 ...	Little Piney, U. S.	50 lbs.?	N.E. to S.W.	3½ P.M.	Stone-fall; sp. gr. 3·5. Pulaski county.
	May 7 ...	Parma			....	fireball.

	July	6 ...	Parma	....	....	....	fireball.
		11 ...	Plaisance	....	....	....	ditto ; also at Zurich ?.
	Aug.	7 ...	at sea, 44° N. and 42° W. ...	....	....	streak 1′	a fine fireball.
		13 ...	Parma	....	....	....	fireball.
k		26 ...	Albania	large	N. to S.	streak 20′?	quick ; from a point to nearly daylight.
l	Sept.	3 ...	Parma	....	....	....	fireball; September 13 ?.
		10 ...	Ghent	....	....	....	ditto.
	Oct.	6 ...	Plaisance	....	....	....	ditto.
m *	Nov.	...	Mexico (Nopalero)	....	W. to E.	2 P.M.	at a height of 1400 metres ; trail of light and detonation.
	Nov.	1 ...	Russia	....	....	....	fireball.
		6 ...	Parma	....	....	....	ditto.
n		8 ...	Edinburgh	2 > moon	N.W. to S.E.	5″	increased gradually from size of Venus.
*		8 ...	Prague	....	....	....	fireball.
		9 ...	Antigua	....	E. to W.	daybreak	ditto ; followed by 3 detonations ; streak.
		10 ...	Parma	....	....	....	ditto.
		12 ...	?	....	....	....	ditto.
o		29 ..	Naples	large	W. to E.	....	before sunset ; turned back and went N.E. to S.W.!
	Dec.	18 ...	Breslau	....	S.W. to N.E.	streak 4″	fireball.
p1840.*	Jan.	8 ...	Apenrade ; Altona	⅓ moon's *d.*	E.S.E to W.N.W.	tail 1′	large, quick, bright ; casting shadows ; detonation.
	Feb.	6 ...	Sandwich Islands	= moon	N.W. to S.E.	....	bolide.

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[a] 1836.* January 12. Cherbourg. Seemed to rotate on its axis ; crackling, whistling sounds heard ; low down in sky whilst visible ; a dark cavity apparently perceptible in the nucleus. 1835 according to Buchner. Apparently about 1000 feet high, going at the rate of ½ a mile in a second.

[b] November 5. Havre. Private notice. Did not burst ; no tail or train.

[c] 1837.* January 5. Toulouse ; also at Bâsle and Vichy. Bluish over *Toulouse*, N. to S., slow ; 60° high ; made an arc of 55° ; had a small tail, followed by 3 smaller balls ; rose in the N. at 45° elevation, and went across the zenith nearly down to the southern horizon. At *Bâsle*, E. to W. ; greenish ; burst with detonation : seen also at Munich and Hildburghausen ; brilliant ; tail reddish ; lasted 3″ ; great noise ; 1¼ A.M. ; over Vichy, 170 miles high ; 7200 feet diameter, or 2434 metres ; speed with earth 4835 metres a second ; absolute speed in space 32,450 metres ; streak 4′ ?.

[d] April 15 ?. Austria. Possibly January 15, at Mikolowa. There seems to be no mention of this fall in any of the German catalogues.

[e] May 5.* In Mass., U. S.

[f] August 5. Streak lasted several minutes.

[g] August 30. Cork. Began as bright speck in the zenith ; fell rapidly, and became gradually larger than the moon till it burst.

[h] March 17. Vanished 30° above horizon, leaving a reddish trace ; white nucleus, one edge red, the opposite purple or blue.

[i] August 9. Germany. Same as Zurich, Aug. 10 (Wolf's Catalogue) ?.

[j] June 6. Paris ; Cambray ; Lausanne, &c. Over a district of 140 leagues square : this fireball presented nearly the same appearance at all these places, and must have been very high up.

[k] August 26 (August 14, O. Style ?).

[l] September 3. A singular reddish meteoric light, or crimson vapour seen between 10 P.M. and 3 A.M., of the 4th September, in London, like a sheet of fire, accompanied with multitudes of falling stars (see Year Book of Facts for 1840, p. 270).

[m] November.* Nopalero, Mexico. Beginning of the month.

[n] November 8. Edinburgh. Moved nearly straight down.

[o] November 29. Naples. At first W. to E., then when over the Adriatic Sea, turned back and passed over the kingdom of Naples, from the Abruzzi Mountains to Naples, vanishing finally over the bay, S.W. of Sansillippo ; long train, which reflected prismatic colours in the sunlight.

[p] January 8.* Schleswig, &c. High up ; at first no tail, but one was formed subsequently, throwing out sparks whilst it lasted ; 2′ or 3′ after, a sound like cannon for 10″ ; also crackling and rolling sounds ; probably exploded over the German Ocean ; 8 P.M.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1840.	Feb. 6	Brussels	....	S.E. to N.W.	....	fine fireball.
	8	Copenhagen	....	....	....	fireball.
	17	Berne	....	....	....	ditto.
[a]	Mar. 17	Canada	....	....	....	large bolide.
	Apr. 28	Parma	4 > Venus	S.E. to N.W.	slow	ditto.
	May 2	Parma	....	....	....	bolide.
*	9	Kirghiz Steppes, Tartary	....	....	....	Stone-fall; stone 8 inches in length.
*	13	Connecticut, U. S.	> full moon.	S.E. to N.W.	....	large bolide; streak several seconds. Same as next ?.
		Albany, New York	....	....	3 A.M.	streak 3′ or 4′. Detonation in 15″.
	23	Parma	....	S.W. to N.E.	....	large bolide; bluish; 40° high at first.
	29	United States	....	....	....	large bolide.
	31	Parma	....	S. to N.	....	bluish.
*	June 12	Uden, Brabant, Holland	¾ lb.	....	10½ A.M.	Stone-fall; June 11 ?.
*	July 17	Casale, Piedmont	11 lbs.	E. to W.	7½ A.M.	Stone-fall. At Cereseto.
	30	Vienna	....	....	streak 15′	bolide.
	Aug. 2	Frankfort	....	....	....	ditto.
	3	France	....	....	....	ditto.
	7	Naples	....	....	....	ditto.
	13	Peru	....	....	....	fireball.
	16	Toronto	....	....	....	ditto.
[b] *	Oct.	Concord, New Hampshire	large	....	8½ P.M.	meteor and detonation.
	7	Dublin and Dundalk	large	....	....	bright as moon; whitish; 43 miles high.
	18	Paris	4½′ *diam.*	N.W. to S.E.	2½″	fine bolide.
	29	Brussels	....	....	....	bolide.
	Nov. 2	Jorieux, France	....	N.E. to S.E.	....	brilliant.
	Dec. 4	Zurich	....	....	....	fireball.
	25	Moravia, &c.	....	N.W. to S.E.	5″	like a Bengal-light; seen also at Peterwardein.
	27	Mitau	....	N.E. to S.W.	....	large fireball.
	29	Tajilsk	brilliant	N.E. to S.W.	....	ditto, bluish; tail 15 metres long.
1841.	Feb. ?	all over Assam	....	....	....	a splendid meteor.
[c]	25	Parma, &c.	....	....	....	meteor. Same evening also at Cherbourg and Chanteloup.
	27	Parma; Guastalla	....	....	....	two fine meteors.
	Mar. 8	Parma; Guastalla	....	....	2′	fireball; burst.
[d]	15	Princetown, New Haven	....	....	....	large fireball; 840 metres *diam.*; bluish.
*	21	St. Menchould, France	large	....	....	fireball and detonation; or 22 March.
*	22	Grüneberg, Silesia	2½ lbs.	....	3½ P.M.	Stone-fall; sp. gr. 3·72.
	24	Geneva	8 > Venus	....	4″	burst without noise.
	30	Geneva	....	....	....	bolide.
	May 13	Brussels		E.N.E. to W.	5″	burst with sparks and many colours.

			24	Naples	....	....	slow	brilliant.
e		June	9	Angers; Agen; Bordeaux	large	S.E. to N.W.	77° in 5″	slow; cast shadows, 10 centimetres in diameter.
	*		12	Triguèrre, Chateau-Renard	75 lbs.	....	1½ P.M.	Stone-fall; sp. gr. 3·54. Loiret, France.
			14	France	....	....	....	fireball.
		July	4	Blois, Brussels	....	....	....	ditto.
	*		17	Milan	....	....	....	aërolitic; according to Quetelet.
			20	Geneva	....	....	4″ or 5″	no streak or tail; alternately dull and bright.
f		Aug.	10	Iwan, Hungary	....	....	10 P.M.	no meteor or detonation; stones said to have fallen.
g			18	Paris; Rheims	¾ moon	S. to N.	3″ or 4″	horizontal; rapid; no streak or tail; round; cast shadows.
			20	Corfu	....	....	....	fireball.
		Sept.	9	Paris	....	....	streak 1¼′	bright; yellowish-red.
			20	Geneva, &c.	....	....	....	a bright fireball and long tail; high up?.
			28	Paris	....	W. to E.	....	ditto ditto.
			29	Bayonne	....	....	....	fireball.
		Oct.	8	Dijon	nearly = moon	....	slow	like a rocket.
	*	Nov.	5	Bourbon-Vendée, France	11 lbs.	....	....	Stone-fall.
			8	Parma	2 > Venus	E. to W.	....	parallel to horizon for 25°; (or 6th November ?).
			9	Hereford	....	....	....	large; ⊥down.
			10	North America	....	....	....	large bolide; seen in many places.
	*		15	Laugensalza	large	....	....	ditto; burst with a tremendous detonation over the town.
h	*	Dec.	5	Goldberg, Silesia	= full moon	S.W. to N.E.	1′	lighted up all the sky; bluish; detonation ?. 6.45 P.M.
			16	Oels	....	....	slow	oval-shaped fireball.
i			21	Glasgow; Stirling	2 > moon	S. to N.	....	very brilliant; tailed; burst; as light as day.
			29	St. Maixent, France	....	....	....	large bright fireball; burst into several large pieces without noise.
	1842.	Feb.	7	Aargau	....	....	....	fireball.
j			9	Toulouse; Agen	= cannon-ball	S.E. to N.W.	slow	probable least distance from earth 15,540 metres.
			19	Basilico, in Switzerland	> moon	N.W. to S.E.	....	bolide.
			20	Wirtemberg	....	W. to E.	....	ditto.

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[a] 1840. March 17. Canada. Since said to be a false account.

[b] October.* Concord, New Hampshire, U. S. Stone said to have been found, but possibly not meteoric; weighs 3·70 grs.; contains no iron, only silica, magnesia, and a little soda; like dross inside; outside white shining enamel; the composition is very like that, however, of Chladnite.

[c] February 25. A stone or some substance? said to have fallen at Chanteloup in N. France, but very doubtful.

[d] March 15. Princetown, Connecticut, United States.

[e] June 9. Agen, Toulouse, Bagnoles, &c. Supposed to have a geocentric retrograde movement in an hyperbola; apparent speed 77,510; relative as regards earth, 77,092; absolute in space, 74,019 metres per second; moved parallel to the horizon at an altitude of 46°; long blue train of light after; height 67 miles. See Comptes Rendus, vol. xxxii. No. 16. Calculations, &c. by M. Petit. 9 P.M.

[f] August 10. Iwan. Stones not larger than peas said to have fallen, not meteoric, according to M. Haidinger and Ehrenberg, simply pea-iron ore.

[g] August 18. Rheims and Paris. Said to have been 730,400 metres from the earth; 12,800 feet in diameter. (452 miles high?)

[h] December 5.* Silesia, Hirschberg, Breslau, Oderberg, Lukenwald, and other places. In bursting, fell into many stars equal 1st mag. in size. Intense light; some heard a report.

[i] December 21. Glasgow, &c. Tail consisting of various coloured fire, like a rocket; dazzling; oval body.

[j] February 9. Also seen at Paris.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1842.	Mar. 18	Parma	....	....	....	bolide.
	Apr. 11	Charka, India	large	....	streak 4′ to 5′	like a rocket. Streak became curved.
*	26	Milena, Croatia	sp. gr. 3·54	....	3 P.M.	Stone-fall, 2½ lbs. [tion in 2′.
a *	June 3	Montpellier; Toulouse	large, =sun	N.E. to S.W.	20° in 5″	cast shadows; blue; sparks; burst 9¼ P.M.; detona-
*	4	Aumières, Dép. de la Lozère	7 lbs.?	....	....	Stone-fall; or France.
*	12	Toulon	....	....	....	divided with detonation into two parts.
b	July 11	Paris	....	....	station. 3½′	then gradually moved in a circle, 9.10 P.M.; fireball.
c	11	England?	very large	....	station. 2′	only 2° or 3° above horizon; then slowly descended in
	31	Hamburg	....	....	3″	part of streak visible for 10″; greenish. [the N.W.
d	Aug. 5	Silesia?	large	N.W. to S.E.	8.20 P.M.	moved parallel to horizon about 4° high; tailed.
e ?	5	Harrowgate, Yorkshire	....	....	5 P.M.	Stone-fall (Kämtz). Very doubtful.
	9	Hamburg	....	....	streak 7″	greenish fireball; red streak.
f	12	?	15′ *diam.*	N.E. to S.W.	streak 25″	visible 5½″; burst into blue and red fragments and
	12	Département de l'Isère	....	....	5″ or 6″	beautiful meteor; same as last. [sparks.
	Sept. 3	Parma	....	....	....	fireball.
	30	Parma	....	....	....	brilliant; high up; alternately bright and dull.
	Oct. 4	Cambridge	....	....	....	fireball.
	18	Hamburgh	=Jupiter	....	streak 7″	ditto.
g *	Dec. 5	Epinal, Vosges; Langres	large	....	5½ P.M.	ditto; very bright fireball; great detonation.
h *	Oct. 23	Silesia, &c.	large	S. to E.	90° in 3″	brightest at first; sparks; detonation; 8½ P.M.
i *	Nov. 30	N.E. of Ahmedabad	sp. gr. = 3·36	....	....	Stone-fall; a shower (Pogg., vol. iv. 1854, p. 366).
1843.	Jan. 2	Bruges	....	....	....	fireball.
	Feb. 1	Riegersdorf	....	....	....	ditto.
j	5	London; Nottingham	large	N.W. to S.E.	quick	a large mass of fire; also seen in Sussex at Arundel.
	Mar. 20	Hamburg	....	....	....	yellowish.
*	25	Bishopsville, S. Carolina	13 lbs.	....	....	Stone-fall; contains no iron; sp. gr. 3·02.
	Apr. 14	Clermont, France	....	W. to E.	quick	became suddenly extinct without bursting.
	May 4	France	large	....	4″	gave light of sun.
*	June 2	Utrecht	5½+14 lbs.	....	8 P.M.	Stone-fall; two fell; sp. gr. 3·57.
	21	Parma	= moon	....	1′	bolide.
	22	Utrecht	....	....	....	ditto.
*	July 26	Manegaon, Khandeish, India	10 inches *d.*	....	3½ P.M.	Stone-fall; black crust.
k *	Aug. 6	Westphalia; Rhine	....	....	1½ A.M.	bright round disc; 41° high up; suddenly appeared in S.W., detonation in 15″ afterwards.
*	Sept. 16	Klein Wenden; Germany	sp. gr. 3·7	....	½5 P.M.	Stone-fall; 6 lbs. (Nordhausen, near Mülhausen.)
	17	Hamburg	....	....	76° in 7″	slow.
l	22	Hamburg	....	....	9″	like a comet; tail 14′ wide, and 90° long; brilliant.
*	Oct. 2	Pont de Bouvoisin	large	....	2 A.M.	bright tail; detonation after.
	16	England		....		bright streak, for several seconds.

[m]1843.*	Oct.	30	Russia	16 lbs.	....	....	Stone-fall; sp. gr. 3·58; with crust.
*	Nov.	11	Danube	....	....	5 P.M.	a white cloud high up; loud report; aërolitic ?.
		18	Nottingham	3 > ♃	....	....	bolide.
[n]	Dec.	11	Limoux; Meuse, France	very large	....	slow	great bolide, equal sun's light; serpentine motion.
[o] *		21	Zurich, Berne, Alsace	....	....	10 P.M.	very brilliant fireball; two detonations heard.
[p]1844.*	Jan.		Corrientes, Brazil	....	....	2 A.M.	Iron-fall; very large mass, several feet *diam.*
		20	Naples	....	....	....	bolide.
		25	Niort ?	....	....	....	ditto.
	Feb.	8	Parma	....	....	....	fireball.
[q]		12	Wologda, Russia ?	....	S.E. to N.W.	....	horizontal; undulatory motion; greenish streak.
		18	Parma; Grübern	....	....	....	fireball.
[r] ?		20	Hanover	....	....	....	mid-day, during a snow-storm; detonation, but no [meteor seen.
	Apr.	3	Sienna; Naples	....	....	....	fireball.

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[a] 1842.* June 3. Calculations by Petit. See Comptes Rendus, vol. xvi. p. 484. Orbit: hyperbolic, with retrograde geocentric motion; apparent speed 71,288 metres per second; relative 71,085; absolute 74,259. N. to S. 184 miles high at first, 12 miles high at last; 45 miles a second. Also seen and heard to explode at St. Beauzires, and Meuse, Département Lozères.

[b] July 11. Paris. From this Babinet infers it did not rotate on its axis. Same as the next one.

[c] July 11. England ?. Probably the same seen elsewhere. This one large and pear-shaped.

[d] August 5. Seen by Boguslawski, probably at Breslau; had a smoke-like tail; twilight; burst in 10″, leaving a black smoke which slowly ascended, broke up and vanished. Baumhauer, in his Catalogue, refers to the stone-fall same day at Harrowgate.

[e] 1842.? August 5. Harrowgate, Yorkshire. A hot stone, like basalt, fell accompanied by whistling in the air and lightning and thunder, said to have fallen, resembling a stone that fell some years before at Cardiff, further particulars of which latter not obtainable at present. See Pogg. Supp. iv. 1854, p. 366; also l'Institut, No. 457. The Harrowgate stone is described also as containing silver-white metallic-looking particles. N.B. A very doubtful fall.

[f] August 12.? Probably another account from another place of the next one, at Isère. This one is described as having commenced at the Pole Star as a point of light, and like a common shooting-star, increasing to a fireball with a disc of 15′. That part of the streak which was next the part of the fireball which burst, was the first to disappear.

[g] December 5.* Eaufroment, near Epinal, Vosges. Immediately after disappearance a series of detonations like artillery; divided into three parts, one of which seemed to fall down to the ground and roll along a meadow; another re-divided and fell like a rain of fire in Epinal; the third passed like a streak of fire along the declivities of Eaufroment, and seemed to touch the ground on the side of the hills. In July 1851, a small mass of meteoric iron was found in the neighbourhood, the product perhaps of this fireball; weight 843 grammes, or 2 lbs.

[h] October 23.* All over Silesia; long rumbling sounds in the air afterwards.

[i] 1842.* November 30. Between Jeetala and Mor Monnee in Mythee-Caunta (see Edinburgh Journal of Nat. Phil., xlvii. p. 53).

[j] 1843. February 5. At Nottingham a blood-red mass of fire to S.W.; 55 miles a minute?; low down near horizon; 8 P.M.; seemed very near to the earth.

[k] August 6.* Appeared in the S.W. The bright round disc gradually dissolved itself into small serpentine portions.

[l] September 22. Hamburg. This large tail or streak-band of light lasted 5″.

[m] October 30.* Russia. At 20 wersts, S.W. of Werschne-Tschirskaja, Stanitzka, on the Don.

[n] December 11. Limoux, &c.; also at Commeray, and other places. No tail; head threw off in advance, sparks. Remarkable meteor; 5 P.M.

[o] December 21.* Zurich, &c. Though foggy at the time, the whole country was lightened up for several seconds; the noise heard in the Vosges.

[p] 1844.* January. Entre Rios, Mocarita, Brazil. Fell with great noise and light (see Phil. Mag. vol. x. 1855). So hot when it fell that it could not be approached nearer than 20 or 30 feet.

[q] February 12. At Usting, in the Government of Wologda. Bright nucleus, composed of many separate stars; tailed.

[r] February 20.? Hanover. Possibly a clap of thunder only.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1844.	Apr. 11 ...	Edinburgh	large	N. to S.	slow, 5½″	dark red-coloured fireball.
*	29 ...	Killeter, co. Tyrone	sp. gr. 3·76	....	3½ P.M.	Stone-fall. No meteor; many small ones; musical sounds in the air.
	May 11 ...	Hamburg	....	....	....	golden-yellow meteor; red train.
	12 ...	Milan	....	....	....	fireball.
	July 10 ...	Hamburg	....	....	....	very beautiful; golden-yellow.
*	20 ...	Parma; Nurenberg	⅔ moon	....	9 P.M.	detonation 4′ afterwards: also Bamberg and Brussels.
	24 ...	Brussels	....	....	....	fireball.
	27 ...	Bruges	....	....	....	serpentine course; reddish.
	31 ...	Parma	....	....	....	fireball.
	Aug. 8 ...	Brittany	....	....	....	ditto.
	10 ...	Hamburg	= Venus	....	....	greenish fireball.
	16 ...	Darmstadt; Frankfort	....	....	....	fireball.
	Sept. 4 ...	Bombay	very large	E. to W.	streak 20′	streak or train of light, large and bright.
a	5 ...	Overall, Silesia	very large	E. to W.	8″, slow	nearly horizontal; reddish streak; conical.
b	10 ...	Belgium; Bruges	large	....	2′	at Bruges like a rocket, 20′ wide and 7 metres long.
	20 ...	Belgium	....	....	....	fireball.
	24 ...	Naples and S. Italy	....	....	....	ditto.
	30 ...	Lombardy	....	....	....	also one at Hamburg same night.
?	Oct. 2 ...	St. Andrew's, Cuba..........	....	....	....	explosive meteor; aërolitic?.
	8 ...	Vals	....	S.S.W. to N.N.E.	slow	horizontal; small tail.
	10 ...	Bonn	....	....	....	fine meteor.
	15 ...	Bombay	large	....	....	large meteor.
c *	21 ...	Laysac, France	3 lbs.?	... .	6.45 A.M.	Stone-fall and detonation?; sp. gr. 3·55.
d b *	27 ...	Parce sur Sarthe	= moon	E. to W.	2″ or 3″	dazzling; loud detonation 3′ or 4′ after. France.
	Nov. 2 ...	Bombay	....	....	4″	brilliant meteor.
	17 ...	ditto..........................	....	....	2″	ditto ditto. Also on the 18th, 19th, 20th and 21st Nov.
e *	20 ...	Laysac; Aveyron, &c.	very large	E. to W.	streak 40″	brighter than moon; conical; 2 A.M. Great and numerous detonations.
	20 ...	Laysac, S. France	½ d. moon	N.E. to S.W.	3 A.M.	round; silver-white.
	Dec. 8 ...	Paris and other places	....	N.W. to S.E.	....	fireball; not well seen; streak from zenith to horizon.
	11 ...	Limoux	....	N. to S.	....	beautiful meteor.
f 1845.*	Jan. 16 ...	Cette, S. France	large	N. to S.	10 A.M.	fine bolide; day-light; great explosion and noise.
?	20 ...	Grüneberg, Silesia	....	N.W. to S.E.	....	remarkable fiery meteor and tail; detonation?.
	27 ...	Hamburg	....	....	....	fireball.
	31 ...	Nottingham	....	....	....	tailed; red streak.
	Feb. 17 ...	Paris	....	....	....	bolide.
	Mar. 10 ...	Hamburg	....	....	....	ditto.
	29 ...	London	....	....	....	curious stationary meteor.
	May 1 ...	Dijon	....	E.N.E. to W.S.W.	slow	bluish-white.
	June 13 ...	Villeneuve, St. Georges	= moon	N.N.E. to S.S.W.	slow	reddish streak; round nucleus.

	[g]1845.	June	18 ...	Syria; Malta	? 5 > moon !	....	streak 60′ !	slow, indistinctly seen; two very large together, nearly joined.
			28 ...	Gooiland	....	....	....	fireball.
		July	14 ...	London	....	....	....	fine meteor; tailed.
			16 ...	Belgium	....	....	....	ditto.
		Aug.	10 ...	London and Oxford	large	....	....	fireball.
			31 ...	Grenelle, France	....	....	....	ditto.
*		Sept.	1 ...	Fayetteville, N. Carolina	....	....	....	meteoric light and loud detonations; Aug. 31 ?.
			6 ...	Rhine country	> ♃	....	....	greenish; no tail or streak.
			7 ...	Calcutta	....	N. to S.	3″	brilliant; tailed; noise like a bullet whistling ?.
		Oct.	24 ...	Bonn	....	....	streak 4′	tailed; curious variations in movement.
			31 ...	Milan	....	....	....	fireball; no noise.
		Nov.	2 ...	ditto	....	....	....	ditto ditto.
			4 ...	Bombay	....	....	....	ditto.
			20 ...	Cramaux	....	....	....	ditto.
*		Dec.	3 ...	Mentz	?	....	....	burst over the town, a large fireball with much smoke and noise.
			3 ...	Paris	2 > ♃	E.N.E. to W.S.W.	streak 2″	meteor; fine streak; 6.10 A.M.
			9 ...	Bombay	....	....	....	remarkable meteor.
	1846.	Jan.	16 ...	Chalons-sur-Loire	very large ?	N.W. to S.E.	5.45 P.M.	long train; cast strong shadows.
		Feb.	3 ...	Switzerland; France	....	E. to W.	....	large igneous globe; 150 miles high over St. Gotthard.
			10 ...	Caraman, France	very large	....	....	bolide.
			11 ...	Nottingham	....	....	....	ditto.
			21 ...	Collioure, France	....	N.E. to S.W.	quick	two, nearly touching, *i. e.* double; strong light.
		Mar.	1 ...	Toulouse	large	E. to W.	2″	fireball.
			5 ...	Paris	....	S. to N.	....	ditto.
			10 ...	Bonn	brilliant	....	....	cast shadows during full moonshine.

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[a] September 5. Silesia. At Hirschberg; horizontal; slow; E. to W.; like a wine-decanter; greenish-yellow tail; of 4′ or 6′ in width; brilliant. Also seen at Posen; must have been very high up; detailed accounts sent in from 35 places; burst into several bright stars, which vanished, leaving only a reddish streak; at Breslau, like a large bright lamp; moved in a curved arc of 50° in length; tail $1\frac{1}{2}$° long.

[b] September 10. Bluish; at first a point, then much larger when falling; $4\frac{1}{2}$ centimetres diameter.

[c] October 21.* Laysac. There is some doubt whether the stone said to have been found, was meteoric; it is doubtful where even it is preserved.

[d] October 27.* 9.40 P.M. Also seen at Angers = moon (see Note A, from vol. xx. of Comptes Rendus, p. 1103).

[e] November 20.* Laysac, Lozère, &c., and other places. Seen 25° above horizon; dazzling; noise followed in 1′. The one at 3 A.M., said to have been a distinct and different one; perhaps doubtful. Comptes Rendus.

[f] January 16.* Cette; also at Laysac.

[g] June 18. Ainab and Lebanon, near coast. Very great and brilliant meteoric light, double headed ?. A large (?) meteor seen at same time in Lat. 36° 41′, Long. 13° 14′; however, Sir W. S. Harris considers this was an electrical phenomenon. See Year Book of Facts for 1849, p. 273–274.

[h] Note A. October 27, 1844. Petit thinks this an intra-stellar body, *i. e.* one that traverses space from one star or sun to another, and which meeting our solar system, merely traverses it to return again to the stellar system from which it came. Petit's calculations give, from the observations made of this meteor from different points, velocity = 77,600 metres per second as regards the earth, and $v. = 73,540$ metres absolute velocity in space per second; and consequently it describes an hyperbola round the sun with a direct heliocentric movement, *i. e.* it does not describe a comet's orbit.—*Note.* Observations on meteor movements must always be too imperfect to be relied upon in these kind of calculations.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
[a]1846.	Mar. 21	Toulouse; Arièges	⅓ *d.* moon	N. to S.?	slow, 2″	brilliant; equal moonlight; satellite of earth?.
	22	Bagnères de Luchon	....	....	....	set a barn on fire?; like a wheat-sheaf; 3 P.M.
	31	Upper Silesia	....	....	quick	bright silvery; short tail.
[b] *	May 8	Macerata, Ancona	1 lb.+	....	9¼ A.M.	Stone-fall and detonation.
[c] *	June 3	Moreton Bay	= moon	E. to W.	....	bright light; great detonation.
*	7	Darmstadt	1 lb.	....	....	Stone-fall? (Poggendorff, vol. iv. 1854, p. 377).
	19	Rhenish Provinces	....	....	....	bright fireball; no noise heard.
[d]	20	Autun, France	12 inches *diam.*	⊥ down	1′	8.30 P.M. Fell giving off small fireballs; violet.
	21	Belgium; Bavaria; Baden	large	N. to S. ⊥ down	....	lost in a shower of sparks. Also at Darmstadt; Palatinate, &c.
	29	Parma	ditto	....	....	fireball.
	July 12	Gloucester	= moon	....	....	downwards from zenith; cloudy.
	12	Paris	2 > ♃	S.S.E. to N.N.W.	10.15 P.M.	bolide.
[e]	23	Toulouse	large	....	....	ditto; satellite of earth, according to Petit.
	25	Gloucester	ditto	....	....	ditto.
	31	Altona and other places	....	....	....	ditto; = next?.
[f]	Aug. 1	Cassel; Bamberg	½ *d.* moon	W. to E.	....	burst; hissing sound?; sparks; brilliant; tailed.
[g]	10	Ireland, co. Down	....	....	....	Iron-mass and meteor?.
	17	Dijon	....	N.W. to S.E.	....	bell-shaped; reddish tail.
	24	St. Apre; Dordogne	....	E. to W.	streak 3′ or 4′	10½ P.M. Luminosity covered one-fifth sky; sparks.
	25	Nottingham	4 > ♃	....	9¼ P.M.	fireball.
	Sept. 15	Wrenbury, Cheshire	like an orange	....	....	bright; long streak or tail.
	25	Paris	6 > ♃	S.S.E. to N.N.W.	streak 6″	ditto ditto; quick; 9.52 P.M.
[h] ?	25	London; Nottingham	large, 15′ *d.*	towards S.E. ⊥	streak 50″	brilliant; 9.45; detonation?; reddish phosphorescent streak.
[i] *	Oct. 9	Paris; Orleans, &c.	⅓ *d.* of moon	S.W. to N.E.?	2″	brighter than moon; oval; burst with detonation.
	10	Ferty sous Jouarre	....	....	....	fireball.
	13	Prausnitz	....	....	....	tailed bolide.
[j]	17	Ramsgate; London; Wales	brilliant	....	....	coruscations; same as the next.
[j]	17	Frankfort; Coblentz	large	N.W. to S.E.	6 P.M.	nearly horizontal; oval; also seen at Dijon.
	24	Silesia; many places	ditto	....	6.45 P.M.	burst into small sparks; no noise; left a small dark cloud for 2′.
[k]	Nov. 9	Dijon; France	= cannon-ball	W. to E.?	strk. 2′ to 15′	slow; horizontal at 60° high; yellowish; long tail.
[l] *	11	Lowell; Mass., U.S.	= sun's *diam.*	....	5′	brilliant; detonation; aërolitic?; 9 P.M.
	15	Hamburg	....	....	....	large meteor.
[m]	18	Breslau, and other places	....	....	....	like a fiery serpent; no noise. Silesia.
	19	Dijon; Avranche	....	....	....	large fireball; = 9th Nov.?.
	23	Berlin	....	....	streak 19½″	fireball.
	Dec. 1	Grotthau	....	S.E. to N.W.	....	bolide.
	7	Jura	....	....	....	fine bolide.
	7	Bombay	....	....	....	a large bolide.

1846.		Dec. 21 ...	Parma	....	....	....	remarkable bolide; day-time, A.M.
	*	25 ...	Minderthal, Bavaria	17 lbs.?	....	2 P.M.	Stone-fall; several; near Schönenberg; sp. gr. 3·75.
[n]	?	Summer ...	Richland, S. Carolina, U. S.	sp. gr. 2·32	....	....	ditto; 6ozs. In Shepard's collection; fell during a thunder-storm.
[o]1847.		Jan. 6 ...	Grunbinnen	....	S.E. to N.W.	....	left a streak varying in intensity; no noise.
[p]		10 ...	Zohten and Vienna	> ♃	N.W. to S.E.	5 P.M.	divided into two; one falling ⊥ down, and one nearly stationary for 7′.
		Feb. 3 ...	Nottingham	large	....	....	bolide. Feb. 5?.
		10 ...	Vienna	....	....	....	ditto.
		11 ...	Versailles	....	....	....	ditto.
		21 ...	Bonn	....	....	....	a fine meteor.
	*	25 ...	Marion, Linn. co., Iowa	50+46+3	....	3 P.M.	Stone-fall; sp. gr. 3·58. Several, together 99 lbs. (75?).
	*	Mar. 19 ...	Aberdeenshire	= moon	....	....	exploded with noise over sea? Also seen at London?.
		28 ...	Bonn?	large	....	3″ or 4″	long tail; bright.
		Apr. 11 ...	Algiers	....	....	....	bolide.
		May 9 ...	Bonn	> Venus	....	....	yellowish-white.
		10 ...	Bonn	....	....	....	reddish-yellow.
		26 ...	Oxford	....	⊥ to N.E.	streak 12′	bluish-white; 15° high.
		June 29 ...	Parma	....	....	....	bolide.
[q]	*	July 14 ...	Braunau, Bohemia	42+30 lbs.	....	3½ P.M.	Iron-fall; sp. gr. 7·71. Two fragments fell with detonation.

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[a] March 21. Petit says this meteor may be a satellite of the earth, with a retrograde geocentric motion. Apparent velocity = 14,157 metres; greatest distance from earth 15,355; least distance 11,974 metres. S. to N.?

[b] May 8.* Near Monte Milone; several fell of about 1 to 6 lbs.; resembling the stone of Klein-Wenden.

[c] June 3.* Moreton Bay, in Australia.

[d] June 20. Autun. Disappeared finally in sparks.

[e] July 23. Toulouse. Real *d.* 100 metres; distance from earth at moment of disappearance 47,000 metres; apparent speed 9500 metres per second; real speed 9480 metres; time of revolution 12,286 seconds; retrograde movement in R. A. 5 miles a second (27 miles high, and 320 feet diameter).

[f] August 1. Cassel. First seen at an altitude of 80°.

[g] August 10. Co. Down, Ireland. An iron said to have fallen and been picked up, but either the whole story is a hoax, or the iron itself purely artificial.

[h] September 25.? At Nottingham a large meteor; in Kent a great meteoric light in zenith; moved downwards from zenith. One account says it exploded with noise; 61 miles high; N. by 10° W.; rate, 24 miles in a second. Apparently seen also at Cambridge, and in Wiltshire.

[i] October 9.* Paris. Also at Chartres and Troyes; detonation very great; fell 55° down and burst; long streak and tail; seemed to be in a state of fusion.

[j] October 17. Frankfort; also seen at Darmstadt. At Dijon, in France; pale blue; slowly descended in an arc of 45° in 1′; left a streak for 5′ or 8′; larger than Jupiter; W. to E.; lost at 15° above horizon.

[k] November 9. Dijon. Light as day. The luminous streak lasted 2′, then gathered itself up at each end, forming a roundish light near its central part, which lasted for 15′ visible. This was a most brilliant meteor; apparent size that of an 8-lb. cannon-ball.

[l] November 11.* Lowell. A stone of 442 lbs. said to have been discovered having a disagreeable smell. There is much doubt whether this was really meteoric.

[m] November 18. Breslau, &c. Left a bright cloud for 10″, composed of three parts. Many places in Silesia.

[n] 1846.? Summer. Richland, S. Car. Contains no metallic iron, and must be considered rather a doubtful meteorite.

[o] 1847. January 6. Towards south from zenith.

[p] January 10. At Vienna, according to Buchner; moved W. to E.; left behind a bright indented streak, which seemed to wind round upon itself like a cirro-cumulus cloud that remained visible for 10′, gradually shifting; according to Faye, a proof the meteor must have passed into the atmosphere.

[q] July 14.* Braunau, Hauptmannsdorf. Meteor seen; one large explosion, and two red streaks of fire fell; the two masses of iron were found at about 6000 Vienna feet apart.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1847.	Aug. 9 ...	Brussels	12′ *diam.*	....	5″ slow	irregular; cast shadows; like a bright cloud of smoke.
	14 ...	Bonn and other places	....	....	....	a fine meteor.
	17 ...	France	....	N. to S.	8″	a fine fireball.
[a]	19 ...	Paris; Dieppe	....	S.S.E. to N.N.W.	....	quick down; left a streak for some time after.
	26 ...	Bonn	....	....	....	fireball.
[b]	Sept. 7 ...	Bombay; Poonah	large	N. to S.	5″ or 6″	bright as moon; bluish, reddish; burst; sparks.
	Oct. 11 ...	Bruges	....	to E.N.E.	....	long tail; 2 A.M.
	17 ...	Wrenbury	....	S.W. to N.E.	....	fine bolide; long streak; whizzing noise?.
	18 ...	Paris	5′ *diam.*	....	2″ or 3″	great light; long tail.
	24 ...	Darlingford	....	....	....	bolide.
	29 ...	Bonn	....	....	....	reddish fireball.
	30 ...	Bombay	large	E. to W.	streak 30″	brilliant; burst; horizontal; dazzling as a Bengal light.
	Nov. 7 ...	Trebnitz, Silesia	....	....	slow	bright fireball.
	11 ...	Benares	....	....	streak 10′	bolide.
	16 ...	Paris	2 > ♃	W. to E.	....	ditto.
	19 ...	Paris; Versailles	7 > ♃	....	25° in 1½″	ditto.
[c]	20 ...	Oxford	large	towards S.W.	7′	nearly stationary for 7′; irregular speed.
	23 ...	Birkenhead	....	....	....	large fireball.
	26 ...	Oels and other places	....	....	....	a fireball; burst. Also at Erdmannsdorf.
	29 ...	Bonn	....	....	8″ for 90°	most brilliant at the 4th second.
	Dec. 13 ...	Dublin	....	....	....	fireball.
	12 ...	Nottingham	3 > ♃	....	....	bluish; tailed.
	8 ...	Paris	2 > ♃	S. to N.	....	bolide.
	13 ...	Breslau	....	....	streak 6 or 7″	tail 4° long; rapid; serpentine movement.
	8 ...	Münster?	....	....	streak 50″	fireball; observed by Heis.
	11 ...	Paris	....	S.E. to N.W.	....	brilliant.
[d]	8 ...	Forest Hill, Arkansas	....	....	3 P.M.	Stone-fall. Violent explosion. Stone 2½ in. in diam.
1848.	Jan. 9 ...	Edinburgh	½ *d.* moon	N. to S.	slow, 1½″	burst while expanding itself. 1849?.
	11 ...	Parma	....	....	....	bolide.
	12, 13 ...	ditto	....	....	....	ditto.
	19 ...	Hirschberg	....	....	....	ditto.
	20 ...	New York, U. S.	large	W. to N.	streak 12′	bright fireball.
[e]	21 ...	Aix; Parma?	30′ *diam.*	....	4″	very large and bright; 10° above horizon; green.
[f]	27 ...	Buckinghamshire	large	S.W. to N.E.	3″	pear-shaped and tailed; double-headed; by day-light.
	Feb. 2 ...	Wrenbury	large	....	....	green, with crimson border.
[g] *	15 ...	Dharwar, India	4 lbs.?	....	1 P.M.	Stone-fall; sp. gr. 3·51; 12 inches in diameter.
	22 ...	France	large	....	....	large bolide.
	22 ...	[illegible]?	12 > Sirius	....	....	cast shadows; bluish; same as last?.
	24 ...	Madras	....	....	....	fireball.

1848.		Mar.	8 ...	Breslau	....	....	....	straight down. 1847 ?.
[h]			8 ...	Slough; Bath	> moon	E. to W.	22″	kite-shaped, tailed; horizontal; gradually increased [in size.
[i]			29 ...	Oderberg	= moon	....	streak 30′	streak visible half an hour.
		Apr.	6 ...	Oxford	....	N. to S.	....	bright, by twilight.
			18 ...	Oxford	= a cricket-ball	S. to W.	....	purplish; yellowish; by twilight.
			30 ...	London	....	N.E. to S.W.	3″	divided into two parts, like a Roman candle.
		May	7 ...	Bonn	....	....	....	fireball.
			19 ...	Silesia	....	....	....	large bolide; or 20th May.
			24 ...	Aix-la-Chapelle	....	....	....	fine bolide.
[j]	*		20 ...	Maine, U. S.	sp. gr. 3·45	S.E. to N.W.	4½ P.M.	Stone-fall; 1¼ oz.; explosion heard over 40 miles.
		July	12 ...	Nottingham	½ *d.* moon	E. to W.	20° in 3½″	slow; bluish.
			23 ...	Bonn	....	....	slow	fireball.
			29 ...	Bonn; Aix; England ?	....	....	....	brilliant; no tail; burst; cast shadows; no noise.
		Aug.	28 ...	Aix	....	....	3″ or 4″	meteor.
			29 ...	Paris	....	....	....	ditto.
		Sept.	1 ...	Brussels; Caen	....	W. to E.	slow	horizontal; greenish; brilliant.
[k]			4 ...	Sussex; Nottingham	⅔ *d.* moon	S.W. to N.E.	streak ½ to 3′	brilliant; burst, and one-third fell down in sparks.
			8 ...	Pisa	....	N.W. to S.E.	....	fireball as large as an orange.
			28 ...	Parma	....	....	....	fireball.
		Oct.	27 ...	Oxford	large	....	....	white; tailed.
			29 ...	Bombay; Poonah	large	W. to E.	streak ½′	horizontal first, then fell down into sea; dazzling.
		Nov.	1 ...	Bombay	....	....	....	fireball.
			9 ...	Nottingham	5 > ♃	....	....	ditto.
			15 ...	Aix	....	....	....	ditto.
			16 ...	Bombay	....	....	streak 6″	ditto.
			29 ...	Lincolnshire	....	....	1′	not tailed. 7 A.M.
		Dec.	2 ...	Bonn	....	....	....	fine meteor.
[l]	*		27 ...	Shie, Krogstadt; Norway	sp. gr. 3·54	....	evening	Stone-fall; 850 grammes; preserved in the Museum at Christiania.

[a] August 19. Paris. Went 42° in a second; at first 134 miles high, then finally 42 miles; period of 373,397 years ?.

[b] September 7. Bombay. Changed its course from N. to S. sweeping round nearly at right angles. Should be 1848, not 1847.

[c] November 20. Oxford. Curious; first moved from zenith to 45° of altitude, then nearly stationary 7′, then moved slowly on towards S.W.

[d] December 8. Arkansas, U. S. Stated by Shepard to be a myth and invention.

[e] January 21. Had a small scattered tail on each side; resembled melted metal.

[f] January 27. Silver-white; fell from 60° high to 30°.

[g] February 15.* Dharwar, S.E. of Negloor, at the junction of the Wurda and Toongabudra rivers.

[h] March 8. At Bath, as large as a cricket-ball; 4 A.M.

[i] March 29. Also seen at Neubrandenburg; the nucleus was of a bluish colour; dissolved without noise into separate stars; the tail or streak gradually curved up and shrunk into a ragged cloud-like form.

[j] May 20.* Castine in Maine. Contains nickeliferous iron. 1¼ lb. ?

[k] September 4. Also seen on N. coast of France, and in Isle of Wight. A remarkable meteor.

[l] December 27.* Krogstadt. Fell on to the ice; nearly as large as a child's head; resembles the stone of Blansko, Moravia, in composition. The stony portion contains about 50 per cent. of olivine.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1849.	Jan. 28	Bath	2 > ♃	....	....	bluish.
	Feb. 24	Madras	....	....	....	large meteor.
	Mar. 6	London	large	....	....	white, then greenish-red.
a *	19	Bombay; Poonah; Surat	=¼ moon	S.W. to N.E.	30° in 2″	brilliant; greenish; burst; 6½ P.M.; detonation.
	23	Bombay; Khandalla	....	....	....	large meteor.
	26	Cochin-China	large	S.E. to N.W.	....	green; red trail; burst.
	April 4	Delhi, India	....	N.W. to S.E.	slow	brilliant; moved horizontally nearly.
	10	Ahmednuggur, India	3 > Venus	W. to E.	....	bright meteor.
b	13	Bombay; Poonah	large	N.W. to S.E.	streak 20″	bright as moon; bluish; egg-like.
c	26 or 19	Bombay; Khandalla	....	N.W. to S.E.	slow	brilliant; burst.
	30	Liège	....	....	slow, 30″	oval fireball; divided into two; day-time; no tail.
	30	Poonah, India	....	....	....	fireball.
	May 2	Bombay	....	....	....	bolide.
	4	Paris	2 > ♃	S.E. to N.W.	....	ditto; by daylight, at 5.30 P.M.
	6	Kurrachee, India	large	S.W. to N.E.	afternoon	well-defined globe; greenish; fell below horizon; no noise.
	26	Bonn	2′ *diam.*?	....	2¾″	brilliant; yellowish; fireball with visible disc.
	June 17	Cambridge, Mass., U.S.	5* to > Venus	W. to E.	....	brilliant; pale orange; broke into several fragments, which did not fall down. July 16?
*	25	Kurrachee, India	large	S.E. to N.W.	10 P.M.	cast shadows; burst; sparks; loud detonation 1′ to 5′ after.
	July 10	Nottingham	5 > ♃	....	slow	bluish; no tail.
	12	Nottingham	¼ of moon	....	....	oval; blue; reddish sparks.
	27	Poorbunder, India	....	⊥ down	5″	brilliant; streak left; sparks.
	Aug. 25	Chesterfield	2 > ♄	N. to S.	slow	nearly horizontal; conical body; tail and small sparks.
d *	Aug.	Kumadau, Africa	....	....	noon	aërolitic meteor (according to Livingstone).
	Oct. 30	Orkneys	....	....	....	a fine meteor; one also seen at Dublin.
*	31	Cabarras co., N. Carolina, U.S.	sp. gr. 3·63	W. to E.	3 P.M.	Stone-fall; 19lbs. Meteor not seen; three reports heard.
	Nov. 1	Tampa, Florida	....	....	....	brilliant meteor seen in the evening.
e	2	Swansea; Flint	½ moon	E.S.E. to W.N.W.	8″, slow	orange-red; 5 P.M. Also seen at Nottingham and Dublin.
	5	Chester; Nottingham; Bucks	> ♃	E.N.E. to W.S.W.	5″	bolide; head composed of 7 or 8 balls; streak 2′.
	7	Mazagon, Bombay	large	W. to E.	5″	streak visible for 2′; burst; 80 miles high.
	8	Bombay	4 > Venus	W. to E.	....	gave a streak.
*	9	Asseerghur & Mazagon, India	4 > Venus	E. to W.	9 P.M.	bright as moon; loud detonation.
f *	13	Italy; Tripolis	large	E. to W.?	several sec.	Stone-fall and meteor; reddish; brilliant; burst into small balls; 6¼ P.M.
	19	Bonn; Aix	....	....	1½″	streak 15″ duration.
	Dec. 12	Shorapore, India	4 > ♀	⊥ in S.W.	rapid	burst with sparks; greenish; bright, casting shadows.
g	19	Durham; Perth; Belfast	2′ *d.* to 15′ *d.*	S.W. to N.E.	76° in 15″	slow, horizontal; split into two at 6° above horizon; streak for 30″?
h	21	New Haven, U.S.	....	....	....	bolide.
	23	Leicestershire	....	....	....	fine tailed meteor.
	30	Weedon; Aylesbury	4′ *diam.*	....	....	round; burst; sent out a tail at an angle of 18° from its direction.

h	*	Aug.	11 ...	Chinese Tartary	12 > Venus	s. to n.	slow	burst into fragments; loud detonation in 20″; bluish.
i	*	Nov.	1 ...	South Carolina	....	....	....	several meteoric explosions and meteors this day.
	1850.*	Jan.	2 ...	Germany	....	....	....	detonating meteor. See Supplement for details.
	*		9 ...	Bonn; Köhlengraben..........	= moon	....	3½ A.M.	meteoric light; vivid; detonation after.
			30 ...	Cherbourg	= Venus	....	3½″	had a streak; moved straight down.
j		Feb.	5 ...	Sandwich, Kent	6* to ⅓ moon	....	station. 1¾′	burst and moved eastwards; red sparks dropping ⊥ [down; curious.
			7 ...	25° N., 66° E., at sea.........	⅛ d. moon	....	....	fireball.
			10 ...	at sea	⅛ d. moon	....	....	rapid; left a streak; small tail.
k	*		11 ...	Penzance to Durham?	= d. of moon	N.N.W. to S.S.E.	2″ to 5″	loud detonation over Biggleswade 2′ after; 10¾ P.M.; streak lasted 5′.
			13 ...	Bonn	large	....	5.28 P.M.	cast shadows; brilliant fireball; reddish.
			13 ...	Nottingham.......................	½ moon	....	9.35 P.M.	fireball; pear-shaped; bluish; ⊥ down; dazzling; 1½′.
l			22 ...	London; Aylesbury, &c. ...	= d. of moon	S.S.E. to S.?	3″ or 4″	clearly defined; ⊥ for 7° or 8° downwards; the last part divided itself into several stars.
		Mar.	6 ...	Surat, India	....	E. to W.	15″	bolide; = Sirius.
			17 ...	Aylesbury	....	....	....	ditto.
	?	Apr.	1 ...	Aden	....	....	....	brilliant fireball; detonation ?.
			18 ...	Dessau................................	....	....	....	fireball, of a greenish colour.

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[a] March 19.* Bombay; seen also at Surat, Poonah, Sholapore, Aurungabad, Asseerghur, Ahmednuggur, and over an area of 300 miles square. Two detonations in about 1¼′ to 3′, heard at Aurungabad. Burst into sparks; 4′ *d.* to 15′ *d.* Probably a stone fell from this meteor. For an account of this meteor, see British Association Reports for 1850, p. 127.

[b] April 13. Bombay; *v.* = 30 miles per second ?. Seen also at Hingolee, a distance of 300 miles from Bombay.

[c] April 19; also Malabar; 7 P.M.

[d] 1849.* August. Kumadau, South Africa. From Dr. Livingstone's description, a detonating meteor, not a stone-fall; at least no stone was picked up.

[e] November 2. Swansea. Vertical over Dublin; oval; dazzling; also seen at Carlow and Drogheda; did not burst.

[f] November 13.* Italy. Seen in the southern sky. Varied in colour; a bright cloud visible 1½ hour after; according to some a detonation heard about 15 minutes (!) after bursting. Seen also like a stream of fire between Tunis and Tripolis, where a shower of stones fell; some of them into the town of Tripolis itself. See Phil. Mag. for 1850; also the Transactions of the Royal Society, and Boguslawski's Catalogues.

[g] December 19. Also seen at Edinburgh, Carlisle, and Nottingham, Longford, and at Ireland. Had only a small streak or tail; was 88 miles high, probably over St. Kilda, Ireland; seen over a distance of at least 300 miles by 140. For a full account of this meteor, see Brit. Assoc. Reports for 1850, p. 109.

[h] August 11.* Private communication from J. W. Atkinson. Globular in form; the fragments after bursting visible for 10″ or 15″; and some seconds again after that the sound of the explosion; about 12¼ A.M., 11, 12 Aug.

[i] 1849.* November 1. See Prof. Shepard's account. In the evening a fine display of shooting stars. Silliman's Journal.

[j] 1850. February 5. About 30 miles high when first seen, at Sandwich.

[k] February 11.* This meteor was seen at Bedford, Rugby, London, Oxford, Greenwich, Montgomery. Mr. Glaisher has given a long account of it in the Phil. Mag. vol. xxxvi. 1850. Explosion heard in one to five minutes over 50 miles square. Height when first seen 84 miles, when burst only 19 miles; real velocity about 30 miles a second. At 50 miles distance, appeared as large as the full moon, as at Hartwell; at 100 miles, rather larger than Venus; moved by jerks; reddish, yellowish, bluish; had no tail, but a luminous train; after the explosion luminous balls and particles dropped down to within 10 miles of the earth. Moved in a parabolic orbit ?.

[l] February 22. No noise heard; this meteor was perhaps seen in Derbyshire, and in Germany, as at Bonn.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1850.	Apr. 21 ...	Breslau	....	....	25″ or 30″	bright meteoric light, increasing and decreasing; burst as it sank below horizon.
	May 2 ...	Bombay	....	....	....	clear white bolide; no tail or streak.
a *	21 ...	Bonn	¼ *d.* moon	....	9½ P.M.	greenish-blue; 4′ after a detonation; varied often in size.
b *	June 5 ...	N. France, Caen, &c.	nearly = moon	S.W. to N.E.	9¼ P.M.	bright; tail 10° long; sparks; detonation in ½ a min.
*	6 ...	Dijon, Tonnerre, &c.	large	S.E. to N.W.	11¼ A.M.	meteor; great detonation over 30 square miles.
c *	10 ...	Bombay	large	S.W. to N.E.	10 P.M.	brilliant; increased in size; detonation in 15″.
	16 ...	New Haven, U. S.	= Venus	....	slow 2″	seen in full day-light.
*	22 ...	Oviedo, Spain	large	....	....	meteor; detonation; *stones* said to have fallen.
	22 ...	London	= *d.* moon	....	3½″	oval; ⊥ down for 15°.
	24 ...	Aigle, France	....	....	....	bright meteor; sparks.
	July 1 ...	Bombay	....	S.E. to N.W.	....	bolide.
	4 ...	Nottingham	3 > ♃	....	2″	brilliant meteor.
?	5 ...	Grantham; Boston	....	....	2″	bolide; said to have burst with slight smoke and noise [over Boston.
	12 ...	Paris	2 > ♃	S.S.W. to N.N.E.	....	ditto.
	15 ...	Paris	2 > ♃	N.E. to S.E.	....	bolide.
	Aug. 10 ...	Tipperary	= moon	N.E. to S.W.	streak 30″	red, then bluish.
	10 ...	Paris	....	N.N.W. to S.S.E.	....	bolide, very brilliant. 11·35 P.M.
	11 ...	Paris	2 > ♃	S.W. to N.E.	10″	ditto.
	12 ...	Penzance	¼ *d.* of moon	N.E. to S.W.	15″	ditto; brilliant.
	14 ...	Nottingham	5 > ♃	....	2″	ditto.
	12 ...	Paris	2 > ♃	....	3″	ditto; no tail or streak.
	Sept. 7 ...	Toulouse	> Venus	....	4½″ for 25°	slow; horizontal.
d ?	Sept. ...	Barcelona, Spain	....	....	....	Stone-fall; sp. gr. 8·12; iron?; electrical?.
e	30 ...	Cambridge, U. S.	⅔ moon	N.E. to S.W.	9 P.M.	pear-shaped; bluish; streak for 30′; 50 miles high.
	Oct. 6 ...	Aix-la-Chapelle; Bonn	....	....	....	white; left a streak.
	9 ...	Hereford	large, 4′ *d.*?	W. to N.	slow	burst; bluish; larger than a cricket-ball.
	13 ...	Toronto, Canada	....	....	45° in 1″	brilliant, with scintillations.
	24 ...	Bonn	large	E. to W.	1½″	seen behind clouds like a flash of lightning.
	Nov. 6 ...	Bombay	large	N.W. to S.E.	3″	burst; comet-like; streak for 20′. Nov. 14?.
	8 ...	Paris	2 > ♃	N.W. to S.E.	2″	bolide.
	14 ...	Berlin	⅓ moon	....	streak 3″?	yellowish (or 15th November).
	28 ...	Nottingham	4 > ♃	....	slow	bolide.
	29 ...	London; Oxford, &c.	⅓ moon	....	....	dazzling; nearly stationary for some seconds; tailed.
f *	30 ...	Bissempore, Shalka	2 feet *d.*	....	3½ A.M.	Stone-fall; in India, Bancoorah, West Burdwan.
	Dec. 5 ...	Oxford; Nottingham	> Venus	S. to N.	3″ for 25°	bluish.
	8 ...	Shorapore; Nizam	= Venus	....	....	yellowish; streak of light for several seconds.
	9 ...	Yorkshire	....	....	....	bright; tailed.

		24 ...	France	....	....	....	
1851.?	Jan.	...	Embden, Germany	....	....	....	a meteoric explosion in atmosphere; aërolitic?.
?		8 ...	Beerb-hom	large	....	....	sunshine at time; burst; black mass seen to fall.
		11 ...	Aix-la-Chapelle	....	....	....	fireball; also seen at Tegau.
		13 ...	Senftenburg	....	....	....	ditto (or 14th Jan.).
		19 ...	Holstein; Eutin	....	....	....	large bolide.
	Mar.	11 ...	Caffraria, S. Africa	?	....	....	fireball; low down near ground, parallel to it; hissing [noise.
*	April	17 ...	Gütersloh, Westphalia	2 lbs.	N.E. to S.W.	8 P.M.	Stone-fall; two fragments; sp. gr. 3.55.
		27 ...	Beeston; Durham	½ *d.* of moon	N.E. to N.W.	streak 5″	light as day; burst; bluish. Also at Oxford.
	May	22 ...	Ennore, India	large	....	....	purple and greenish.
		24 ...	Andes, S. America	large	E. to W.	....	large fireball; earthquake about the same time.
	June	1 ...	Calcutta	large	N. to S.	....	greenish.
		20 ...	London; Bath	large	....	streak 3½′	bolide; did not burst; slow.
		22 ...	London	....	....	....	ditto.
		22 ...	Belfast	=moon nearly	towards E.	streak 7′	ditto, near apparently; reddish; sparks before it.
*	July	7 ...	Epinal, France	....	....	....	bolide and detonation.
		6 ...	Paris	2 > Venus	E.N.E. to W.S.W.	4″	ditto; stopt once for a moment; streak lasted 8″.
	Aug.	21 ...	Cherbourg	2 > Venus	....	....	ditto.
		12 ...	Paris	2 > Venus	N.W. to S.E.	quick	ditto.
	Sept.	2 ...	Huggate	⅔ *d.* moon	....	....	moved upwards; reddish.
		19 ...	Calcutta	½ *d.* moon	N.E. to S.W.	5″	bright.
		20 ...	Oxford; Surrey	=½ *d.* moon	N.W. to N.E.	3″ or 4″	slow; long streak; light as day; also at Nottingham.
	Nov.	3 ...	Nottingham	large	....	....	at first stationary; very blue.
		4 ...	Bramcote	½ *d.* moon	....	....	orange.
[h] *		5 ...	Tarragona, Spain	sp. gr. 3·8	N.E. to S.W.	5½ P.M.	Stone-fall; 3 fragments found; many stones fell ?.

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[a] June 6.* Two explosions heard at Montbard, Châtillon, Dijon, Tonnerre, Choisy-le-Roi; the meteor itself was only seen at Genlis, Côte-d'Or.

[b] June 5.* N. France; Passy, Loiret, Paris, Compiègne, Beauvais, Chartres, Caen, Rouen, and Hâvre. At first about ⅓ size of moon; when last seen near Hâvre, nearly the size of the full moon; detonation heard by some; stones were supposed to have fallen either in Normandy or Picardy. Moved 10° in a second about; seen 25° above the horizon; yellowish, purplish; *v.*=27 miles per second; height 32 miles over Normandy. Lighted up the country near Hâvre like day-light; streak lasted several minutes.

[c] June 10.* Noise lasted for 30″. Also seen at Kishnahur.

[d] 1850.? September. At the beginning of the month; Dr. Joaquin Balcells of Barcelona, relates the fall of a thunder-stone (?). Sp. gr. 8·12; dark coloured, very hard; conical form; made a hole in the ground. Said to contain no arsenic; some silica and alumina and sulphurous iron. Certainly rather doubtful; and perhaps a nodule of pyrites.

[e] September 30. Bright train or streak; like a rocket; brilliant; sparks; also seen in Maine, Conn., Mass.; long tail; bright light *cumuli* clouds left which became curved; seemed to have a rotating motion at first.

[f] November 30.* Shalka; this stone contains a mineral which M. Haidinger calls "*Piddingtonite.*" The sp. gr. of this stone is 3·41—3·66. See Journal of the Asiatic Society of Bengal, vol. xx. p. 852, and vol. xiii. p. 885.

[g] December 3.* Prince of Wales's Straits. A specimen brought back by the Captain of the 'Investigator.'

[h] 1851.* November 5. Between Nulles and Vilabella, 16 leagues S.E. of Barcelona, and 4 leagues E. of Tarragona in Spain; at 5½ P.M.; clear day; brilliant fireball seen high up; with a luminous tail, which changed to a misty cloud and lasted 20′. A tremendous noise 40″ after the fireball disappeared; seen over a distance of 20 leagues. Many stones fell between Valls and Tarragona; at Nulles, one weighing 19 lbs. 8 ozs. In the villages of Vilabella and Brafim, fragments of 1 and 5 lbs.; very hot when first picked

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1851.	Nov. 18 ...	Cherbourg	....	....	....	bolide.
1852.	Jan. 3 ...	Cracow	....	....	....	ditto.
	19 ...	Leipzig........................	½ moon	N.W. to S.E.	....	ditto; burst without noise.
	Apr. 2 ...	Toulouse	....	....	....	ditto; 17½ miles in a sec.; 105 ft. *d.*?; 10 miles high.
[a] *	June—Dec.	Koruman, South Africa	....	....	night	aërolitic (according to Dr. Livingstone); stone not [found, however.
	July 3 ...	Dreux, France..................	6 > ♃	....	slow, 8″	bluish.
	12 ...	Edinburgh, Perth	⅔ *d.* moon	towards N.E.	....	also at Dunse and Glasgow; also Belfast?.
	13 ...	London	large	....	....	changed colours.
	June 1 ...	St. Isabel, California	....	W. to E.	....	brilliant.
[b]	Aug. 12 ...	Sidmouth........................	= full moon	nearly stationary	2′	like a bar 7° long and 1° wide; intense light for 30″.
	22 ...	St. Ives	½ *d.* moon	....	slow	whitish; left a streak.
	Sept. 24 ...	Aylesbury	large	....	....	bolide; August?.
*	4 ...	Mezo-Madaras..................	18 lbs.	S.W. to N.E.	....	Stone-fall; sp. gr. 3·50. Siebenbürgen, Transylvania.
	25 ...	St. Ives	....	W. to E.	....	large and curious.
[c] ?	June—Dec.	Great Tschuai, Africa.........	....	....	....	aërolitic (according to Livingstone).
	Sept. 28 ...	Silesia; Breslau	large	⊥ down	8¾ A.M.	seen over all Silesia; tailed; during sunshine; no noise.
*	Oct. 13 ...	Borkut, Hungary	12 lbs.	....	3 P.M.	Stone-fall; sp. gr. 3·24.
*	17?...	Chihuahua, Mexico	large	W. to E.	8 A.M.	meteor; fiery tail; slow; detonation followed.
	Nov. 21 ...	Paris	2 > Venus	W.N.W. to E.S.E.	5′	bolide; burst.
	Dec. 11 ...	Germany	....	....	....	detonating meteor. See Supplement.
[d] ?	17 ...	Dover	½ *d.* of moon	S.E. to N.W.	5 A.M.	fell down into sea with a hissing cracking noise and [spray.
1853.*	Feb. 10 ...	Girgenti, Sicily	sp. gr. 3·76	....	....	Stone-fall; about 7 inches in length.
*	Mar. 6 ...	Segowlee, Patnah	sp. gr. 3·42	....	noon	some 30 stones, one 14½ lbs. India.
	July 2 ...	Paris	2 > Venus	E.S.E. to W.N.W.	3″	ditto; streak lasted 5″; beautiful train.
	Aug. 1 ...	Paris	2 > Venus	W.N.W. to E.S.E.	2″	bolide.
	7 ...	Glasgow	½ *d.* of moon	N.E. to S.W.	1″	fireball; moved nearly straight down. 10.30 P.M.
	7 ...	Paris	2 > Venus	W. to E.	....	ditto.
	9 ...	?	....	....	....	divided into two parts.
	26 ...	Mazzow	....	....	streak 10′	bolide.
	26 ...	Algiers........................	....	....	....	bolide; no noise.
	Sept. 2 ...	Paris	6 > Venus	S.W. to N.E.	4″	bolide; brilliant; fine train for 10″.
	12 ...	France	6 > Venus	S.W. to N.E.	streak 6′	brilliant; 84° in 4″.
	30 ...	Leven, Fifeshire	1st* to ⅔ moon	N.E. to S.W.	2″ or 3″	rather up towards zenith. 11¾ A.M.
	Oct. 26 ...	Pomerania	large	....	....	left a spiral trail.
[e] *	28 ...	Norfolk; Nottingham, &c....	¾ *d.* of sun	S.W. to N.E.	4 P.M.	day-light; straight down, detonation 3″ after.
	Nov. 11 ...	Paris	2 > Venus	E. to W.	2″	ditto; streak 7″.
*	Dec. 21 ...	Germany	....	....	....	detonating meteor, observed by J. Schmidt.
1854.	Aug. 1 ...	Nottingham	[illegible]	S.E. to N.W.	3″	brilliant; equal ½ *d.* of moon.

		July	[illegible]	[illegible], Germany	....	....	....	aërolitic (according to Wolf's Catalogue).
	*		17	Germany	....	....	....	detonating meteor.
		Aug.	1	Göttingen	....	....	streak 35″	bolide.
			16	Nottingham	3 > ♃	....	1½″	no streak; divided itself into two balls.
			29	Paris	2 > Venus	W.N.W. to E.S.E.	3″	bolide; beautiful train.
			30	St. Ives	large	....	slow	bolide.
	*	Sept.	5	Fehrbellin, Potsdam	6 lbs.	S.W. to N.E.	....	Stone-fall; after a detonating meteor.
		Oct.	7	Nottingham	¼ *d.* moon	S.W. to N.E.	rapid	fireball.
f	?		18	Tabarz, Gotha	1⅓ oz.	....	....	Iron; sp. gr. 7·737.
			22	Hitchin, Herts	¼ *d.* moon	N.E. to S.W.	rapid	white and brilliant; burst without noise.
		Nov.	22	Paris	2 > Venus	W. to E.	quick	bolide; long train; reddish.
		Dec.	8	Vienna	....	....	....	ditto.
			24	ditto	....	....	....	ditto.
	1855.*	May	11	Oesel Isle, Baltic	57 lbs.	....	....	stone; sp. gr. 3·7 (2·5—3·8). [Sp. gr. 3·53.
	*		13	Bremevörde, Hanover	25+10+? lbs.	....	5 P.M.	three stones = 6lbs. + 3lbs. + 325 grammes in weight?.
		June	6	Paris	2 > Venus	N.W. to S.E.	....	bolide; burst.
g	*		7	Ghent, Flanders	....	....	7.45 P.M.	stone; sp. gr. 3·30; weight 700 grammes.
		July	13	Nottingham	3 > ♃	....	slow, 2″	bluish.
		Aug.	3	ditto	¼ *d.* moon	towards W.N.W.	2″	bluish; suddenly vanished.
h	*		5	Lincoln co., Tenn., U. S.	3¼ lbs.	from E.	3½ P.M.	stone; sp. gr. 3·20; near Petersburg (2·5—3·3).
			10	Nottingham	5 > ♃	....	1″	bluish; streak 25° long.
		Oct.	14	ditto	4 > ♃	....	....	large; tail divided into two; oval.
		Dec.	11	Edinburgh	30′ *d.*	....	....	violet; round; tail and sparks thrown off.
			19	Nottingham	= moon's *d.*	N.E. to S.W.	streak 10′	bolide.
			21	Bulwell	4 > ♃	....	slow 4″	blue and round fireball; brilliant; 18° in 1″.

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up; showed metallic particles, and black crust. Resembles the Blansko stone in composition. Extracted from a curious *brochure* by Dr. Joaquin Balcells, Nat. Hist. Professor at Barcelona.

[a] 1852.* June to December. Koruman. A detonating meteor.

[b] August 12. Seen in Germany, at Munster ?.

[c] June to December.? Africa. Apparently a detonating meteor, judging from Dr. Livingstone's description; possibly the same as that seen at Koruman. Schuia lake ?.

[d] December 17.? Dover. Aërolitic ?; noise and detonation, lasted some time; tail 5 or 6 times longer than the body; the nucleus appeared in the centre of a large black cloud: for a curious account of this phenomenon, see Transactions of the Royal Society, sitting of January 27, 1853.

[e] October 28.* *Stones* said to have been picked up in Hanover. This meteor is stated to have been 140,000 yards high at time of explosion; moved previously 15° in 3″. Seen likewise in Suffolk.

[f] 1854.? October 18. A shepherd is said to have found this iron, still burning-hot on the ground, at the fort of the Inselberg. Eberhard found it to contain 92·757 iron, 5·639 nickel, cobalt 0·791, phosphorus 0·862, schreibersite 0·277. It is not stated that any meteor was observed or detonation heard. Buchner's Feuermeteore, p. 121.

[g] June 7.* St. Denis-Westrem, near Ghent. 700 grammes = 1 lb. 4 ozs. of Vienna. Fell without any meteor having been observed, and without any loud noise or detonation, merely with a kind of rushing, rolling, whistling sound; it was picked up while hot, and smelling of sulphur; crust thin.

[h] August 5. Lincoln co., Tenn., U. S. The fall was preceded by a loud report like that of a large cannon, followed by four or five less reports, &c. The fragment picked up approached from the east, and appeared whilst falling to be surrounded by a "milky" halo about two feet in diameter, and fell about 180 yards from a person who picked it up. When dug out, it was too hot to be handled.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
1855.	Dec. 21 ...	Paris	4′ *diam.*	S.S.E. to N.N.W.	11 A.M.	bolide; day-light; large as a goose-egg.
[a]1856.	Jan. 7 ...	Oxford; Brighton; Havre ...	$\frac{2}{3}$ *d.* of moon	N.W. to S.E.	2″	fell nearly straight down; 45° when first seen; 5 P.M.
[b] *	Feb. 3 ...	Nottingham; Brussels; Geneva; Paris; Baden, &c....	15′ *d.* 6′ to 15′ in *d.*	S.W. to N.E. S. to N.?	5″ 3″ to 4″	green, orange, red. At Paris, white, and burst with sparks without noise; 8.10 P.M.; intense white to blue; great detonation 5′ after. Apparent diameter 2400 feet; velocity of 13 miles in a second; moved by jerks.
[c] ?	9 ...	Pau, S. France	....	....	daytime	great detonation overhead for 20″; no clouds; aërolitic?.
	29 ...	France	....	....	5 or 6″ for 70°	gave a bright light and threw off sparks.
[d] *	July 8 ...	Alabama, U. S.	8 inches *d.*	....	4 P.M.	detonation 3′ after first appearance. Colum., Ala., U.S.
	30 ...	Paris	large, 4′ *d.*	E. to W.	streak 4′	cast shadows; white to red; hissing sound?.
	Aug. 23 ...	Brussels; Namur	large	....	....	50 miles high at first; 15 miles least distance; 300 feet *d*?.
	25 ...	St. Ives; Portsmouth	large	....	slow	curious; 8 P.M. Same as last?.
	31 ...	Nottingham	$\frac{1}{3}$ moon	....	....	reddish-yellow; began as a 3rd mag.*; suddenly vanished.
[e] *	Sept. 17 ...	near Civita Vecchia	large	⊥ down	10$\frac{1}{2}$ A.M.	fell into sea with spray and hissing; aërolitic?.
	Oct. 27 ...	St. Ives	....	....	....	fine meteor.
	24 ...	Paris	2 > Venus	W.N.W. to E.S.E.	streak 6″	ditto.
	29 ...	Laibach	....	....	streak 30′	large bolide.
[f] *	Nov. 12 ...	Trenzano, Brescia	17 lbs.+	....	....	Stone-fall; three fell; one 17 lbs. Lombardy.
	Dec. 13 ...	Nottingham	....	....	....	large and curious meteor.
?	Apr. 8 ...	Colmar, Haute Rhine	....	....	....	aërolitic meteor? or April 6?.
1857.	Jan. 9 ...	Ashford, Derbyshire	large	....	....	bluish; bright as moon.
*	Feb. 18 ...	Vienna; Hungary	large	....	3 A.M.	detonating meteor. Brilliant; divided into two.
*	28 ...	Parnallee, Madura, Carnatic	37 lbs.+150	....	noon	stones; two large ones. India.
[g]	Apr. 11 ...	Minesota, U. S.	> full moon.	E. to W.	4″	9 P.M.; streak serpentine, lasting 2′ to 10′.
[h] *	15 ...	Kaba, Hungary	7$\frac{1}{2}$ lbs.	....	evening	stone; said to contain an organic resinous matter!
	16 ...	Nottingham	8 > ♃	downwards	slow	bolide.
	July 20 ...	St. Ives	....	stationary	5′	afterwards passed slowly downwards; brilliant.
	22 ...	Paris	2 > Venus	S.S.E. to N.N.W.	....	bolide.
	Aug. 11 ...	Paris	....	S.E. to N.W.	....	ditto.
	25 ...	Portsmouth; St. Ives	$\frac{1}{3}$ *d.* moon	....	2″	burst into fragments and sparks; no noise.
	Sept. 29 ...	Nottingham	6 > ♃	....	11° in 1·50″	bluish; curious; no streak; no noise.
*	Oct. 1 ...	Yonne, France	....	....	4$\frac{1}{2}$ P.M.	stone.
*	10 ...	Ohaba, Transylvania	29 lbs.	....	evening	stone; sp. gr. 3·1. Carlsburg, Siebenburgen.
[i]	29 ...	Paris	....	E. to W.	....	fireball; broke into 4 or 5 separate balls. See Supplement.
[i] *	Dec. 17 ...	Germany, Westphalia, &c....	large	N.W. to N.E.	4.55 P.M.	fireball; 4 or 5 detonations in 1$\frac{1}{2}$′ at a height of 4 miles.
[illegible]	27 ...	Peru, [illegible]	....	[illegible]	2.30 A.M.	Stone-fall; sp. gr. [illegible] Three stones fell.

1858.		Jan.	10	Leeds	....	N.W. to S.E.	....	burst with reddish sparks; brilliant.
			31	Cornwall	= moon	....	....	crescent-like; elongated; fell rotating and giving off sparks.
l		May	4	Aylesbury	electric?	....	....	ignited globe, set fire to a straw yard, exploding with noise.
	*		19	Kakova, Bannat	29 lbs.	....	8 A.M.	stone; in Hungary, near Oravitza, sp. gr. = 3·38.
			31	Nottingham	¼ *d.* of moon	....	2½″	burst and disappeared; bluish.
	*	Aug.	1	Heredia (Costa Rica)	sp. gr. 3·70	....	....	Stone-fall; according to Harris, S. Mexico.
m	?		4	Berlin, Stettin, &c.	....	....	6″	fireball; detonation ?.
			12	Paris	2 > Venus	S.S.E. to N.N.W.	streak 3′	bolide.
			13	London	⅓ *d.* of moon	....	....	tail 2° long; whitish-red; sparks; uniform; vanished as a point.
n	*	Sept.	13	N. of France; Rennes	....	S.E. to N.W.	6″	cast shadows; 7 P.M.; strong detonation ?; rapid.
	?		13	Germany	....	....	....	detonating meteor. Same as last ?.
		Dec.	2	Herefordshire	....	slow ⊥ down	streak 3″	afternoon by day-light.
o	*		9	Aussun, Haute Garonne	16+90 lbs.	....	7 P.M.	2 stones; sp. gr. 3·4; Montrejean, France; 51 kilos.
1859.		Jan.	2	Somersetshire	2 > ♃	....	....	bolide.
		Feb.	23	Nottingham	1* to ⅓ moon's *d.*	....	slow, 8″	burst; blue colour.
		Mar.	18	Wolverhampton	....	....	....	magnificent meteor.

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[a] January 7. Left a serpentine white semi-luminous train; seen in some places for 5′ and even 10′ after; at first like a well-defined sword or column of light. At Havre or Caen N.E. to S.W.; and some persons fancied they heard a noise. Also seen in Wilts and Isle of Wight.

[b] February 3.* At Paris 15′ *d.*, at Brussels 6′ *d.*: explosion heard at Boesinghe-lez-Ypres; seen also at Carlsrühe, in the Vosges, at Namur, and generally from St. Gotthard to Brest. 150 miles high when first seen; went 300 miles in a few seconds; thick purplish train; oval.

[c] February 9. One account says 15 centimetres large, another as large as an egg, or 4′ diameter; like a burning cauldron?.

[d] July 8.* Alabama. Fireball first seen 35° above horizon; fell downwards until within 10° elevation, when it instantly disappeared; this, as seen by one observer, left a dense vapoury white cloud, which continued visible, gradually assuming a bent and zigzag shape for 15′.

[e] 1856. September 17. Seemed to fall into the sea close to a vessel, after a loud detonation; the date given for this meteor in Buchner's work on Fire meteors, is 24th May, 1855.

[f] November 12.* Trenzano (according to Haidinger).

[g] 1857. April 11. Minesota. Left a bright streak 1° wide from the E. to W. horizon, lasting 2′ or 3′; a portion of 15° for 10′.

[h] April 15. Kaba, Debreczin. The resinous matter like ozocerite; possibly absorbed in passing through the atmosphere, or from the earth into which it would have fallen when hot.

[i] October 29.? Paris. The separated fireballs seemed to hop and then fall perpendicularly; immediately after they had vanished, the tail or streak, which seemed to have been formed out of numberless sparks, quickly disappeared.

[j] December 17.* At Olsberg in Westphalia, 4 or 5 detonations heard 1½′ after it had burst; over Luxemburg, 10 or 11 miles high. Heis says it was not more than 7½ miles high over the spot where it exploded. Colour yellowish-green; divided soon into 4 fragments.

[k] December 27.* At Quenggouk, near Bassein in Pegu (see Haidinger's account in the Transactions of the Imperial Academy at Vienna, vol. xlii. 1860). Two stones picked up about 1 mile apart, which seemed to dovetail; a third fell about 10 miles further. A great meteor seen by some two or three times larger than the moon; moved very slowly; great detonations heard also.

[l] 1858. May 4. Hit a cow; smell of sulphur; no stone found; probably electrical.

[m] August 4.? Seen also at Münster and Oderberg. See Buchner's work, pp. 171 and 181. This meteor is said to have twice changed its direction each time of its apparent bursting, and sending out reddish-coloured sparks.

[n] September 13.* At Neuilly, and also in Brittany.

[o] December 9.* Canton de Montrejean (Haute Garonne); one stone of 43 kilogrammes fell at Aussun, and one of 8 at Clarac, according to Comptes Rendus.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Duration; rate; hour.	Remarks, &c.
[a]1859.*	Mar. 28	Harrison co., Kentucky, U. S.	sp. gr. 3·45	....	4 P.M.	Stone-fall; several small ones found after a detonating meteor; 2 lbs.
	30	Nottingham	½ *d.* of moon	towards N.	slow	red, pink, orange. Train of light for 50″; brilliant.
	June 26	London; Yorksh^e; Lancash^e	15′ *d.*	slow ⊥ down	....	no tail; globular.
	July 27	Athens	....	very slow	12″ for 28°	greenish; cast shadows; began and ended as a point.
	15	Paris	2 > Venus	S.E. to N.W.	streak 2″	bolide.
*	Aug. 7	Germany; Westphalia	....	S.W. to N.E.	8¼ P.M.	detonating meteor; tailed; rushing sounds heard.
[b] *	11	New York co., U. S.	6 ozs.	S.W. to N.E.	7.20 A.M.	Stone-fall and detonating meteor; only 6 ozs. picked up; sp. gr. 3·56.
	11	Athens	....	....	streak 3′40″	fine meteor.
*	Sept. 1	W. Tennessee, U. S.	....	....	10 A.M.	day-time; meteoric, detonations over 40 square miles.
?	24	Jacobshof, Switzerland	....	....	11½ A.M.	detonation heard; no fireball seen.
?	24	Edlitz, Vienna	....	....	11 A.M.	strong detonation, and whizzing sounds heard overhead. Same as last?.
	25	Nottingham	....	....	....	fireball.
	Nov. 14	Sandwich Islands	= moonlight	N. to S.	....	fine meteor; moved straight downwards.
[c] *	15	New Jersey, U. S.	⅓ *d.* of sun	N.E. to S.W.	9½ A.M.	rapid; brilliant; tailed; smoky train; detonations.
*	28	S.W. of Bohemia	....	....	....	brilliant bolide; detonation.
	Dec. 5	at sea, 13° 20′ N., 50° E.	....	⊥ down in W.	sunset	left a bright white cloud for 15′, which gradually changed shape.
	9	Münster	⅓ moon	....	....	fireball; in the direction of Brussels.
1860.	Jan. 24	Beeston, Notts	4 > ♃	....	7″	fireball.
	Feb. 11	Sidmouth	....	N.N.W. to S.S.E.	5″	ditto; burst into globular masses.
	Mar. 2	Beeston, Notts	4 > ♃			
[d]	10	Leeds; Derby; Dublin	⅔ moon	E. to W.?	2″ to 5″	ditto; oval, tailed; bar-like.
	14	Beeston	6 > ♃			
[e] *	May 1	New Concord, Ohio, U. S.	700 lbs.	S.E. to N.W.	30° in 3″	Stone-fall; many fell; sp. gr. 3·54.
?	July 6	Baton Rouge, Miss.	large	....	....	large meteor; burst with noise of a cannon; electrical?.
	20	Nantwich; Liverpool	brilliant	....	....	fireball; globular; burst like a rocket.
*	20	United States	= moon	E. to W.	20″	ditto; slow; divided with noise into two; tailed.
[f]	20 or 21	United States	....	W. to E.	....	ditto; as large as a cocoa-nut; different one from the last.
	22	Budleigh Salterton, Devon	large	E. to W.	30″ slow	fireball; parallel to horizon for 45°.
[g] *	14 or 28	Dhurmsala, Kangra, Punjab.	420 lbs.+	N.W. to S.E.	2¼ P.M.	Stone-fall; many large ones; flames in sky and great detonations.
	Aug. 6	New Haven, N. York	large	S. to N.	....	fireball; brilliant; 7¾ P.M.
*	2	Tennessee, U. S.	¾ moon	E. to W.	10 P.M.	ditto; detonation in 3 or 4 minutes.
	Oct. 13	Dover	= ⅓ moon	N.N.W. to S.S.E.	slow	fireball; 25° arc; burst; white nucleus 9½ P.M., and red sparks.
1861.	Jan. 5	Bermuda	....	E. to W.	....	brilliant meteor, followed by a terrific report when over the sea at some distance from land. (New

1860.

[a] 1859.* March 28. Kentucky. Four reports heard like bursting of bomb-shells; then smaller reports, and stones fell hissing through the air over an area of 4 miles square. March 26?.

[b] August 11.* At Bethlehem, New York.

[c] November 15.* A most remarkable meteor. Explosions heard over 55 miles square for two or three minutes; seen in Connecticut, New Jersey, New York, Baltimore and Virginia; report equal to the firing of 1000 cannon. No stones found, probably fell in the water. Proper motion = at least 30 miles a second; orbit hyperbolic?; not therefore a member of the solar system?. Time of flight 2″ for 20° of an arc. It was vertical over the southern part of New Jersey; and would probably fall into Delaware Bay. When overhead, only a flash seen, and loud reports about a minute afterwards, with some curling smoky clouds; visible path about 110 miles in 2 seconds; apparent motion about 55 miles a second, as far as could be guessed. Seen in full sunshine. Height when burst about 4 to 10 miles. Two series of explosions. See Journal of the Franklin Institute for 1860(*).

[d] March 10. Seen also at Bradford, Newport, Salop, Blackburn, and in Cheshire; purple, reddish, greenish after bursting! cast shadows.

[e] 1860.* May 1. Ohio; 12.45 P.M. The meteor appeared of the size of the moon at stations about 25 miles from its direct path; its calculated velocity was 4 miles per second; height when it exploded about 41 miles; it appeared, however, to pass on after dropping the stones. Assumed diameter of the body $\frac{3}{8}$ of a mile; nucleus brilliant; train conical = 12 diameters; black stones fell through the clouds with a whizzing sound directly after the explosions. Detonations heard over 150 miles square. The stones, of which about 30 were found, one weighing 103 lbs., others 36 and 54, &c., fell over an area 10 miles long by 3 wide; the larger ones furthest in the direction of the meteor. At New Concord, the sounds were heard first nearly overhead, and lastly, 45° below the zenith, *i.e.* at a point where the meteor probably first burst. Twenty-three distinct sounds first heard like cannon-shots, and then the sounds were blended together like musketry; lasted 2 minutes about; stones angular.

[f] July 20.* Seen over a length of 1000 miles by 500 in width; and in 13 States about 9.45 P.M. At first a single ball, afterwards divided with a report in about 3′ into two, followed by a train of sparks and fire; bluish; very brilliant; moved extremely slowly, and apparently almost across the entire heavens; seemed very near when almost overhead; absolute velocity in space calculated to have been 26 miles a second; apparent velocity 12 or 13 only. At its nearest approach to the earth about 41 miles distant; was supposed not to fall to the earth, but to have passed off with a convex curve. One of the most remarkable and best observed meteors on record. Train 9° long; distance of first ball from second after dividing, calculated to have been two miles. Appeared to move horizontally.

[g] July 28.* Kangra, N.E. of Lahore, India. For an account of this remarkable fall, see the "Times" newspaper, end of December 1860. A series of shocks and explosions frightened the inhabitants, and shook the mountains; all the phenomena painfully sublime and alarming; lasted a long time; to the noises succeeded flames of fire (12 feet long?), like the flames from a cannon-mouth; then a great shower of meteoric stones ploughed up the earth in numbers. Another account says the fall took place at Dharamsala, July 14. A great fiery body was seen, then a great detonation, which shook the ground, followed by 14 or 15 smaller ones. One stone was picked up which was so intensely *cold* as to benumb the fingers and hands. See Haidinger's paper in the 42nd volume of the Transactions of the Imperial Academy of Vienna. Specimens are being sent to Europe.

(*) Mr. Benjamin V. Marsh, in his Report on this meteor, very reasonably considers the audible explosion, lasting two or three minutes, to be the result of the bursting of the meteor; for though the meteor might really occupy only half a second in bursting, yet in that interval the noise would be distributed over a distance of 20 or 30 miles, and thus the sound would appear to last several minutes to an observer stationed at one spot. It is supposed that this meteor first became luminous at a height of about 100 miles.

CONTINUATION OR SUPPLEMENTARY CATALOGUE.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Hour or Duration.	Remarks, &c.
369.*	?	Constantinople	....	....	....	Stone-fall. Between A.D. 363 and 375.
769.*	May	Persia or Arabia	....	....	....	a shower of stones.
860.	Apr. 9	?	....	....	....	fireball ?.
931.	Oct. 19	?	....	....	....	ditto ?.
979.	Nov.	?	....	....	....	ditto ?.
1039.	Apr. 8	?	....	....	....	ditto.
1095.	Feb. 24	?	....	E. to W.	....	ditto ?.
1118.	Apr. 14	?	....	....	....	ditto ?.
1130.*	?	Kaswin, or Casbin	....	....	....	Stone-fall; two fell with detonation; south of the Caspian Sea.
1151.*	?	?	....	....	....	ditto.
1168.	Dec. 24	?	....	....	....	fireball ?.
1177.	Nov. 28	?	....	....	....	ditto ?.
1226.*	?	?	....	....	....	Stone-fall.
1438.	Summer	Lucerne	....	....	....	fireball.
1529.	Jan. 9	Germany	....	....	....	ditto ?.
1537.	Mar. 7	Babylonia	....	....	....	ditto ?.
1543.	May 4	Pfortzheim	....	....	....	ditto ?.
1560.	Jan. 30	?	....	....	....	ditto ?.
1574.	June 2	Zurich; Frauenfeld	....	....	....	ditto.
1580.	Sept. 21	Stutgardt	....	....	....	ditto.
1596.	28	?	....	....	....	ditto.
1619.	Oct. 15	Frauenfeld	....	....	....	ditto (Oct. 5 in 1st Catalogue ?).
1623.	Mar. 29	Zurich	....	....	....	ditto.
1628.	Mar. 27	?	....	....	....	ditto ? (or April 27).
1630.	June 18	?	....	....	....	ditto.
1634.*	Oct. 27	Charollois, France	....	....	8 A.M.	Stone-fall. Two fell.
1640.	Sept. 25	?	....	....	....	fireball; or 1641.
1643.	Nov. 8	?	....	....	....	ditto ?.
1644.*	?	East Indian Seas	....	....	....	Stones fell on board a vessel. 1643 ?.
1646.	Mar. 15	Reutlingen	....	....	....	fireball.
1682.	31	Niederelb	....	....	....	ditto.
	May 18	Glarus	....	....	....	ditto.
	Nov. 30	Zurich	....	....	....	ditto.
	Dec. 15	ditto	....	....	....	ditto.
1683.	Aug. 12	?	....	....	....	ditto.

1683.	Aug. [illegible]	?	....	....	....	fireball.
1687.	May 26	Zurich ; Berne	....	....	....	ditto.
1698.	27	Zurich	....	....	....	ditto (May 19 in 1st Cat. ?).
1701.	Apr. 6	Montjuif, Barcelona	....	E. to W.	2′	ditto ; burst into several parts ; much light ? 10 P.M.
1704.	Oct. 4	Bay of Barcelona	....	⊥down	....	ditto.
1709.	Mar. 4	?	....	....	....	ditto.
1711.	Mar. 28	Zurich	....	....	....	ditto (31st March in 1st Cat. ?).
	Dec. 28	ditto	....	....	....	ditto.
1719.	30	?	....	....	....	ditto.
1736.	Oct. 1	?	....	....	....	ditto (Oct. ? Schleswig in 1st Cat. ?).
1752.	Dec. 25	?	....	....	....	ditto.
1753.	Nov. 4	?	....	....	....	ditto.
1756.	Jan. 15	?	....	....	....	ditto.
1757.	Feb. 26	?	....	....	....	ditto.
1759.	May 4	?	....	....	....	ditto.
1763.	Apr. 29	?	....	....	....	ditto.
1768.	July 22	Tranquebar, India	....	....	....	ditto : many meteors ?. Not a stone-fall.
1780.	Aug. 10	Lucerne	....	....	....	fireball.
1783.	Sept. 5	Zellerfeld	....	....	....	ditto.
1785.	May 31	?	....	....	....	ditto.
	Oct.	Gotha	....	....	....	ditto.
1786.	Nov.	?	....	....	....	ditto.
1787.	Aug. 7	?	....	....	....	ditto.
1788.	?	Popayan, S. America	large	....	1 P.M.	ditto ; sun shining at time (Humboldt).
	Dec. 3	Geneva	....	....	....	ditto.
1797.	June 20	Berne	....	....	....	ditto.
1799.	Nov. 12	?	....	....	....	ditto.
1801.	Oct. 15	Zurich	....	....	....	ditto.
1803.	June 9	Berne	....	....	....	ditto.
1804.	Dec. 2	?	....	....	....	ditto.
1805.	Nov. 21	Berne	....	....	....	ditto. [the East Indies, in 1st Cat.
1808.	?	Moradabad, India	....	....	....	Stone-fall. In the Calcutta Museum. Same as from
	June 4	?	....	....	....	fireball.
	July 17	?	....	....	....	ditto.
1811.	Nov. 7	France or Switzerland	....	....	....	ditto. Brilliant. Arc of 60° in 20″.
1812.	Oct. 26	?	....	....	....	ditto.
	31	?	....	....	....	ditto.
[a]1815.*	?	Darmstadt	3 ozs.	....	....	stone ; now in the Heidelberg Museum. (1815 ?.)
1816.	Dec. 11	Augsburg	....	....	....	fireball.
	14	Erlach	....	....	....	ditto.

[a] 1815.* Darmstadt. Exact time of fall not known ; probably 1814 or 1815.

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Year.	Day of month.	Locality.	Size or weight.	Direction.	Hour or Duration.	Remarks, &c.
1816.	Dec. 21	?	....	....	....	fireball. (Hungary, 20th Dec. ?)
	22	?	....	....	....	ditto; same as last ?
1818.	Jan. 17	Vermont, United States	=moon	....	....	ditto. Brilliant; followed by 2 smaller ones.
1819.	May 5	?	....	....	....	ditto.
1820.	July 8	Munich	....	....	....	ditto.
	30	?	....	....	....	ditto.
	Oct. 12	?	....	....	....	ditto.
1821.	Mar. 23	Augsburg	....	....	....	ditto.
	Sept. 7	?	....	....	....	ditto.
	Dec. 18	?	....	....	....	ditto.
1822.	June 19	?	....	....	....	ditto.
1823.	Aug. 15	?	....	....	....	ditto.
	22	?	....	....	....	ditto.
1825.	Feb. 7	?	....	....	....	ditto.
?	May 9	Wirtemberg	....	....	....	ditto with detonation ?.
	Nov. 9	ditto; Mittelstadt	....	N.W. to S.E.	....	ditto; burst into reddish sparks.
1826.	Sept. 6	?	....	....	....	ditto.
1827.	March 1	Lavaux	....	....	....	ditto.
	May 21	?	....	....	....	ditto.
	Sept. 7	Estremadura	....	....	....	ditto.
	22	Aschaffenburg	....	....	....	ditto.
	Oct. 7	Zurich	....	....	....	ditto.
	28	ditto	....	....	....	ditto.
1828.	July 30	Aufenau	....	....	....	ditto.
1829.	July 26	Parma	....	....	....	ditto.
	Aug. 23	Wirtemberg	....	S.W. to N.E.	....	ditto; brilliant light.
	Sept. 6	?	....	....	....	ditto.
	Oct. 3	Zurich	....	....	....	ditto.
	23	Cracow	....	....	....	ditto.
1830.	Jan. 16	Paris	....	....	....	ditto.
	Aug. 12	?	....	....	....	ditto.
1832.	Dec. 30	Bonn	....	....	....	ditto.
	Jan. 4	S. Germany and Switzerland	large	N. to S.	1½ A.M.	ditto; serpentine course.
	Aug. 3	Wirtemberg	....	S.E. to N.W.	6″	ditto.
1833.	Dec. 11	Augsburg	....	....	....	ditto.
1834.	Sept. 19	Wirtemberg	....	E. to W.	....	ditto; long train; burst.
	Nov. 4	Munich	....	....	....	ditto.
	Dec. 31	Wirtemberg	....	to S.W.	....	ditto; burst.
1835.	May 10	Weimar	....	....	....	ditto.

1835.	Nov. 19 ...	Wirtemberg	=moon	....	2″ to 3″	fireball.
1836.	Jan. 23 ...	Munich	....	....	....	ditto.
	Nov. 13 ...	Mezel	....	....	....	ditto (Département de l'Ain ?).
	14 ...	Berlin	....	....	....	ditto.
1837.	Jan. 22 ...	Friedrichshafen	....	....	....	ditto.
	24 ...	Munich	....	....	....	ditto.
	25 ...	Augsburg	....	....	....	ditto.
	Mar. 28 ...	Lons le Saulnier	....	....	....	ditto.
	July 9 ...	Berne	....	....	....	ditto.
	Aug. 3 ...	Zurich	....	....	....	ditto.
1838.	18 ...	Wirtemberg	....	E.S.E. to W.N.W.	4′	ditto; streak visible 4 minutes !.
	Sept. 27 ...	Zurich	....	....	....	ditto.
1839.	Jnly 11 ...	ditto	....	....	....	ditto.
	Sept. 13 ...	Parma	....	....	....	ditto.
1840.	Feb. 17 ...	Wirtemberg	....	W. to E.	....	ditto; large fiery tail; also at Berne ?.
	June 3 ...	Wirtemberg and Weinfelden	=moon	to S.E.	....	ditto.
1841.	Aug. 2 ...	Waadt	....	....	....	ditto.
	9 ...	Toronto	....	....	....	ditto.
	18 ...	Paris	....	....	....	ditto.
	Nov. 6 ...	Parma	....	....	....	ditto.
1842.	Apr. 3 ...	Zurich	....	....	....	ditto.
	Oct. 23 ...	?	....	....	....	ditto.
1844.	June 12 ...	Milan	....	....	....	ditto.
	Aug. 5 ...	Hamburg	....	....	....	ditto.
*	Sept. 15 ...	Wirtemberg	....	W. to E.	4½ P.M.	ditto; during sunshine; detonation after.
	Nov. 4 ...	Bombay	....	....	....	ditto.
1845.	Apr. 24 ...	Greenwich	....	....	....	ditto.
	July 29 ...	England	....	....	....	ditto.
	Nov. 6 ...	Bombay	....	....	....	ditto.
	12 ...	Eutin	....	....	....	ditto.
	14 ...	Bombay	....	....	....	ditto.
	22 ...	Wirtemberg; Wurzburg	....	....	....	ditto; also at Treves.
	Dec. 25 ...	Stutgardt	....	W. to E.	....	ditto.
1846.	Mar. 24 ...	Toulouse	....	....	....	ditto.
	May 29 ...	Nottingham	....	....	....	ditto.
	Ang. 26 ...	ditto	....	....	....	ditto.
	Sept. 13 ...	Paris	....	....	....	ditto.
	22 ...	Bâsle	....	S.E. to N.W.	....	ditto; brilliant.
	Oct. 4 ...	Sicily	....	....	streak 19″	ditto.
	Nov. 22 ...	Berlin	....	....	....	ditto.
	23 ...	ditto	....	....	....	ditto.
	28 ...	Bonn	....	....	....	ditto.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Hour or Duration.	Remarks, &c.
1847.	May 15	Teufen	....	....	....	fireball.
	Aug. 7	?	....	....	....	ditto.
	Nov. 17	Nottingham	....	....	....	ditto.
	Dec. 16	?	....	....	....	ditto.
	Nov. 29	Silesia; Vienna	....	....	6¾ P.M.	ditto; large; burst; no noise heard.
1848.	Jan. 20	Rome	....	....	....	ditto.
	Feb. 7	Nottingham	2 > ♃	....	....	ditto.
	Mar. 12	Breslau	....	....	....	ditto.
	Apr. 12	Oxford	....	S.E. to N.W.	....	ditto.
	15	Whitesville	....	....	....	ditto. North Carolina.
	May 10	Woodstock, Oxford	....	....	....	ditto.
[a] ?	July 4	Marmande, Lot et Garonne	7 lbs.	....	....	Stone-fall; a fragment in the British Museum.
	13	Stone-Easton, Somerset	....	....	....	fireball.
	15	Nottingham	....	....	....	ditto.
	29	Bradfield, Berks	....	....	10 P.M.	ditto; also at Bonn?
	Aug. 2	Paris	....	....	....	ditto.
	Aug.	Littau, Olmutz, Moravia	2 > moon	....	15″	ditto; double meteor; 2 fireballs pear-shaped, close together, in line.
	Sept. 1	Dijon	....	....	....	ditto.
	10	Leipzig	....	....	....	ditto.
	11	Aix	....	....	....	ditto.
	Dec. 11	Bonn	....	....	....	ditto.
1849.	Feb. 10	Nottingham	....	....	....	ditto.
	28	Rosehill, Oxford	....	....	....	ditto.
	May 8	Nottingham	....	....	....	ditto.
	31	Hirschberg	....	....	....	ditto.
	June 27	Nottingham	....	....	....	ditto.
	30	ditto	....	....	....	ditto.
	Aug. 3	ditto	....	....	....	ditto.
	6	Rosehill	....	....	....	ditto.
	7	Nottingham	....	....	....	ditto.
	11	Saarbrücken	....	....	....	ditto.
	16	Leobschünitz	....	....	....	ditto.
	Sept. 3	Castle Donington, Leicester[c]	....	N.E. to N.W.	streak 7″	ditto.
	Oct. 20	Aylesbury	....	....	....	ditto.
	28	Leipzig	....	....	....	ditto.
	Nov. 13	Mecklenburg; Breslau	large	....	streak 15′	ditto; brilliant; burst; 4 A.M. No noise.
[b]1850.	Jan. 2	Aix; Bruehl	....	N.W. to S.E.?	3¾ A.M.	ditto; great light for 1′ or 2′, and strong detonation in about 2′.
	Feb. 3	Nottingham	....	....	....	ditto.
	19	Wirtemberg	....	....	....	ditto.

1850.	Feb.	23	Bonn	....	....	....	fireball; cast shadows.
		26	Nottingham	....	....	10″	ditto.
	Mar.	5	Wirtemberg	....	S. to N.	....	ditto; burst.
		7	Nottingham	....	....	....	ditto.
	Apr.	6	Ittendorf	....	....	....	ditto.
	June	1	Nottingham	....	....	....	ditto.
		7	Herrenberg	....	....	....	ditto.
		9	Nottingham	....	....	....	ditto.
	July	6	Wirtemberg	....	S.W. to N.E.	....	ditto; brilliant.
		9	England	....	....	....	ditto.
		23	Leipzig	2′ *diam.*	....	....	ditto.
		28	Münster?	....	....	streak 10′	ditto.
	Aug.	4	Radeburg	....	....	....	ditto.
		5	Marburg	15′ *diam.*	....	....	ditto; burst; brilliant; tailed. Münster?.
		8	Berne; Paris?	....	....	....	ditto.
		10	Aix; Berne?	....	....	....	ditto.
		11	Radeburg	....	....	....	ditto.
		13	Port Madoc	....	....	....	ditto.
		16	Marburg; Leobschunitz	....	....	....	ditto.
		22	Nottingham	....	....	....	ditto.
		29	ditto	2 > ♃	....	....	ditto.
	Sept.	4	Grantham	....	....	....	ditto.
		19	Neunkirchen	....	....	....	ditto.
		21	Darlington	....	....	6″	ditto.
	Nov.	13	Oxford	....	....	....	ditto.
		23	Nottingham	2 > ♃	....	....	ditto.
1851.	Jan.	8	Stutgardt	large	....	....	ditto; brilliant.
		22	Aix and Bonn	....	....	....	ditto. Two different ones.
	Feb.	21	Elberfeld; Barmen	....	....	....	ditto?; an atmospheric phenomenon?.
[c] *		22	Gutenberg; Eifel	=sun	N.W. to S.E.	7¾ P.M.	ditto; burst with detonation and sparks; dazzling.
	Apr.	18	Elberfeld	....	....	....	ditto.
		19	Aix	....	....	....	ditto; intermittent light; large streak.
	May	18	Freiberg	....	....	....	ditto.
	June	11	Frankfort, Hanover, Baden	large	....	....	ditto; tailed; oval.

[a] 1848.? July 4. Marmande. This fragment was from the collection of a Colonel Gabalda of the French army. The entire stone is stated to have weighed 3 kilogrammes and 56 grammes. No published accounts of this fall, apparently.

[b] 1850. January 2. Sky rather overcast at the time; at Crefeld people thought they heard afterwards a rushing sound like birds flying through the air. The noise seems to have been heard over 300 square miles, in Rhenish Prussia; the noise shook the ground like an earthquake. See also Catalogue, page 89.

[c] 1851.* February 22. Also at Neunkirchen; detonation heard at Birkenfeld and the Eifel mountain. Heis calculated its height when first seen at 9 miles, and at 4 (geographical?) miles when it disappeared. Seen also at Boxheim, near Kreuznach.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Hour or Duration.	Remarks, &c.
1851.	Aug. 10	Aix	....	....	....	fireball; bluish.
	Sept. 24	ditto	....	....	....	ditto.
	26	ditto; Dusseldorf, &c.	$\frac{2}{3}$ moon	....	stationary	ditto; at first a point of light; increased, then decreased and vanished.
	Oct. 6	ditto; Bonn, &c.	....	to N.W.	....	ditto; brilliant. Also at Malmedy.
	Nov. 3	Verden, Hanover	....	....	....	ditto. Also at Nottingham ?.
	20	Cracow	....	....	....	ditto.
	Dec. 10	Münster ?	....	....	streak 45″	ditto; followed by a report ?.
1852.*	Jan. 24	Nellore, Madras	....	....	4½ P.M.	Stone-fall. Weight of stone about one maund.
a	May 11	Eitorf; Neunkirchen	> Venus	N.E. to S.W.	8″	fireball; no train or sparks. 1851 ?.
	17	Nottingham	= 3 ♃	....	....	ditto.
	June 12	Pegau, Saxony	....	W.N.W. to E.N.E.	....	ditto; bluish. 1851 ?.
	July 5	Holland; Leicestershire ?	....	....	....	ditto.
	6	ditto	....	....	....	ditto.
*	8	Wedde, Holland	....	....	....	Stone-fall; day-time. In the Gröningen Museum.
	23	Holland; Leicestershire ?	....	....	....	fireball. July 5 ?.
	Aug. 12	Münster	....	....	....	ditto; coloured sparks; intermittent.
	19	ditto	....	....	....	ditto; white, then red, and sparks.
	Dec. 9	Cracow	....	....	....	ditto.
b *	11	ditto; Silesia; Berlin	10′ *diam.*	N.N.W. to E.S.E.	8 A.M.	ditto; brilliant; tailed; detonation. Lasted 9″.
	13	Leipzig	....	....	....	ditto.
1853.	Jan. 16	Kremsmünster	....	....	....	ditto.
	24	Erlangen and Münster	....	....	....	ditto.
	29	Erlangen	....	....	4″	ditto.
	Feb. 14	Cracow	....	....	....	ditto.
c ?	Mar. 6	Wanjka-land, East Africa	....	....	....	Stone-fall. A specimen of 1½ lb. at Münich.
	April 2	Toulouse	....	....	....	fireball.
	June	Münster	....	....	....	ditto; during twilight.
	July 11	Mentz	large	....	3½″	ditto; intense light.
	Oct. 25	Münster	....	....	8″	ditto.
	Dec. 11	Erlangen	....	....	4″	ditto.
1854.	Jan. 1	Hermanstadt	....	....	....	ditto.
	2	Königsberg	....	....	....	ditto.
	21	Neunkirchen	....	....	....	ditto.
*	Mar. 1	Switzerland and Tyrol	....	....	....	ditto; followed by detonation.
	3	Münster	....	....	streak 10″	ditto; no tail or sparks.
	8	Zurzach	....	....	....	ditto.
	12	Wirtemberg; Lintz	....	E. to W.	....	ditto; bluish; whizzing sound ?.
	19	Escheneiler	large	....	....	ditto.
	Apr. 4	Cracow	....	....	....	ditto.

		13 ...	Leipzig	....	....	....	ditto.
		14 ...	Bamberg	....	....	....	ditto.
	May	15 ...	Cracow	....	....	....	ditto.
		18 ...	Leutschau	....	....	....	ditto.
	July	2 ...	Cracow	....	....	....	ditto.
		14 ...	Senftenberg	....	....	....	ditto.
		29 ...	Gera	....	....	....	ditto.
	Sept.	2 ...	Kahlenberg	....	....	....	ditto.
		5 ...	ditto	....	....	....	ditto.
		6 ...	ditto	....	....	....	ditto.
	Oct.	3 ...	Admont	....	....	....	ditto.
	Nov.	11 ...	Münster; Hamm	....	....	....	ditto; small.
*		17 ...	Heppens; Embden, &c.	large	⊥ down	11 A.M.	ditto; burst with detonation. Like a ninepin.
	Dec.	9 ...	Schütenhoffen	....	....	....	ditto.
1855.	Jan.	15 ...	Vienna	....	....	....	ditto.
		23 ...	Bautzen	....	....	....	ditto.
		29 ...	Malmö	....	....	....	ditto.
	Apr.	11 ...	Cronstadt	....	....	....	ditto.
		16 ...	Zara	....	....	....	ditto.
		24 ...	Elberfeld and Lentzenkirchen	....	....	....	ditto (or 25th April).
	May	7 ...	Parma	....	....	....	ditto.
	July	11 ...	ditto	....	....	....	ditto.
	Aug.	12 ...	Münster	large	....	....	ditto?; great light, = $\frac{1}{2}$ moon.
		16 ...	Neufchatel?	....	W. to E.	....	ditto.
	Sept.	8 ...	Rome	....	....	....	ditto.
		22 ...	Vienna	....	....	....	ditto.
	Oct.	1 ...	Kahlenberg	....	....	....	ditto.
		14 ...	Hermanstadt	....	....	....	ditto.
		16 ...	Walkersdorf	....	....	....	ditto.
	Nov.	8 ...	Neunkirchen	....	....	....	ditto.
		8 ...	Gran	....	....	....	ditto.
	Dec.	8 ...	St. Magdalena	....	....	....	ditto. North America.
		27 ...	Zurich	....	....	....	ditto.
		28 ...	Gera	....	....	....	ditto.

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[a] 1852. May 11. Also seen at Frankfort, Bremen, Baden, and Fulda.

[b] 1852.* December 11. Length of its path estimated by Pape at 20 miles; height 13 miles at first, and about 5 miles when it burst. Explosion heard at many places. See Proceedings of the Society of Silesia, vol. xxxi. p. 187. Seen also at Erlangen, 2 > Venus, giving out great light. At Leipzig, 10′ in diameter, at first yellow, then green; burst into sparks without noise, as also at Jena, Lobau, Pegau, and Fulda.

[c] 1853.? March 6. Duruma, Wanjka-land. May this not be the Segowlee meteorite?.

Year.	Day of month.	Locality.	Size or weight.	Direction.	Hour or Duration.	Remarks, &c.
1856.	Jan. 9	Switzerland; Aix	= moon	S.W. to N.E.	6½ P.M.	fireball.
*	Feb. 16	Westphalia	....	....	4 P.M.	ditto; followed by violent detonation.
	Mar. 25	Neufchatel	....	⊥ down	....	ditto; brilliant.
	May 19	Zurich	....	E. to W.	....	ditto; magnificent white meteor.
*	Oct. 5	Bohemia	....	N. to S.?	noon	ditto; detonation heard over 8 (German ?) miles by 2½.
	11	Zurich	> ♃	....	....	ditto.
1857.	Feb. 7	Parma	....	N.E. to S.W.	....	ditto.
	Oct. 29	Paris	....	....	....	ditto; 17 miles high to 4⅓; *v.* = 5 miles. "Heis."
	Nov. 19	Barmen	....	....	....	ditto.
1858.	Jan. 8	Leipzig	....	....	....	ditto.
	10	Neufchatel; Rochefort	....	S.W. to N.E.	9 P.M.	ditto; divided into two; reddish; tailed.
*	27	Switzerland	large	N.W. to S.E.	3.45 P.M.	ditto; curved tail; bluish; detonation.
	Feb. 17	Westphalia	....	N.E. to S.W.	....	ditto; brilliant; no noise. 8¼ P.M.
	June 6	Treves	= moon	N. to S.	....	ditto; 2 A.M.
	7	Westphalia; Holland; Saxony	large	S.W. to N.E.	10 P.M.	ditto; burst into 3 parts at a height of 15 miles; 200 ft. in *diam.* ? "Heis."
	27	Elberfeld	....	S.E. to N.W.	2″ to 3″	ditto.
	28	Münster and Dortmund	....	....	....	ditto; dissolved into sparks.
	July 11	Oldenburg	....	S.E. to N.W.	5″ to 10″	ditto; streak visible 1′ to 3′.
	Sept. 10	Daun, Eifel	= ½ moon	E. to W.	slow	ditto; dissolved into bright clouds; tailed.
	Oct. 3	Westphalia; Neuss	....	....	....	ditto; brilliant. 12.30 A.M.
	4	Clermont; Westphalia	....	....	7.50 P.M.	ditto.
	Nov. 30	Pas de Calais	....	....	....	ditto; streak visible some time.
1859.	Feb. 20	Göttingen	....	....	2″ to 3″	ditto.
	Mar. 19	Elberfeld	....	....	....	ditto; brilliant.
	May 15	Westphalia	....	N.W. to S.E.	4″	ditto; path oblique; no train.
	July 9	Neunkirchen	....	S.W. to S.E. ?	9 P.M.	ditto; splendid; burst without noise.
	Aug. 2	China	....	....	....	ditto; ditto; "Overland Mail, Aug. 10, 1859."
	17	Central Germany	....	E.S.E. to W.N.W.	3″	ditto; brilliant; streak visible a long while; no noise.
	Oct. 20	Dorpat	....	....	....	ditto; two fireballs during an aurora. Oct. 19 ?.
	22	Louvain, Belgium	....	....	4″ to 5″	ditto; long broken tail; reddish.
	27	Dorpat ?	....	....	....	ditto.
	Nov. 9	Giessen	....	N.E. to S.W.	....	ditto; tailed, white oblique path. 6½ P.M.
	11	Darmstadt; Manheim	....	W. to E.	....	ditto; during moonlight; 1½ inch *diam.* 7 P.M.
	14	Borken, Prussia	....	....	....	ditto; brilliant.
	Dec. 8	Darmstadt	....	N. to S.	7 P.M.	ditto; oblique path; 2′ to 3′ in *diam.*
	11	Manheim; Giessen	....	N.E. to S.W.	....	ditto; during bright moonlight. 7.20 P.M.
	25	Erbach, Switzerland	....	S.W. to N.E.	15″	ditto; arc of 30°; burst. 5¼ P.M.
	27	Aarau, ditto	....	....	....	ditto; slow; tailed.
	[illegible]	Zurich	....	S. to N.	6″	ditto.

[a]1860.	Jan. 20 ...	Cassel and other places	....	....	5″	fireball ?; intense and sudden light. 5 A.M.
	Apr. 14 ...	Geldern; Holland	....	....	....	ditto.
[b] ?	June 9 ...	Raphoe, co. Donegal	....	....	2 P.M.	Stone-fall; fell during a storm of thunder and hail.
	13 ...	Dresden	....	S. to N.	....	fireball.
	Oct. 15 ...	ditto..........................	....	....	....	ditto.
	25 ...	Hamm, Westphalia	....	N. to S.	streak 6″	ditto; burst without noise.
	30 ...	Ebstorf	....	E. to W.	....	ditto; long broad tail; dazzling; white.
	Nov. 1 ...	Giessen	....	....	....	ditto; path curved; no tail; bright.
	Dec. 6 ...	Dresden	....	S.E. to N.W.	....	ditto; bluish.
	11 ...	Ittendorf; Aarau	....	....	....	ditto.
	24 ...	Kremsmünster..................	large	....	....	ditto; long tail.

[a] 1860. January 20. Cassel, &c. Night rather dark and cloudy; a light perceived over a distance of 26 geographical miles about 5 A.M. Seen at Friedberg, Odenwald, Hesse, &c.

[b] 1860.? June 9. Raphoe, Ireland; see the Londonderry *Sentinel* of June 15, 1860. It does not appear there was any fireball; the stone resembled friable sandstone; it was seen to fall near Raphoe, and was about as large as a duck's egg. It had neither outside crust nor shining metallic particles; was quite cold and moist when picked up. N.B. June 8 or 9. The fragments of this stone have been mislaid or lost unfortunately.

Note. 1856. February 3. Additional particulars by Prof. Heis of Münster. When first seen, this meteor was 30 geographical miles over St. Gotthard; finally 10½ miles directly over Chalons in France; and if it fell to the ground, would have fallen between Amiens and Cambray; was seen at Berne to fall straight down from the zenith.

Additional authorities and references consulted in the preceding Catalogue, and more especially in the Supplement:—Annual Records of Wirtemberg, 1855; Proceedings of the Society of Natural Philosophy at Bâsle, 1849; Boguslawski's 10th Supplement of the Catalogue of Chladni, Pogg. Ann. for 1854, Part IV.; Neufchatel Journal of Natural History and Philosophy; the Cologne, Manheim, Darmstadt Gazettes; Reports of the Proceedings of the Society of Upper Hesse, 1859 and 1860; Heis' Weekly Review (*Wochnerschrift*) of Astronomy, Halle, 1860; J. Schmidt's Observations; Kämtz's Meteorology; Proceedings of the Societies of Silesia; L'Institut de France; Unterhaltingen für Dilettanten und Freunde der Astronomie, Geographie und Witterungskunde, G. A. Jahn, Leipzig, 1851–1860; Timb's Year Book of Facts, &c.; Monthly Magazine; Gentleman's Magazine; Encyclopædia Metropolitana, 1849, article by W. H. Miller on Meteoric Stones.

TABLE I.

Showing those months in each year from A.D. 1860, arranged backwards, to A.D. 1800, in which Aërolitic Falls or Detonating Meteors have been observed.

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1858.	1857.	1859.	1857.	1860.	1860.?	1860.	1860.	1859.	1857.	1859.	1858.
1852.	1857.	1854.	1856.?	1858.	1855.	1860.	1859.	1859.?	1857.	1859.	1857.
1851.?	1856.	1853.	1851.	1855.	1850.	1860.?	1859.	1859.?	1856.	1856.	1857.
1851.?	1856.	1853.?	1850.?	1855.	1850.	1856.	1858.?	1858.	1855.?	1854.	1853.
1850.	1856.?	1849.	1844.	1850.	1850.	1854.	1858.	1858.?	1853.	1851.	1852.?
1850.	1853.	1847.	1842.	1848.	1850.	1854.?	1857.?	1856.	1852.	1850.	1852.
1845.	1851.	1843.	1838.	1846.	1849.	1852.	1855.	1854.	1852.	1849.	1851.?
1845.?	1850.	1841.	1837.?	1840.	1846.	1851.	1849.	1852.	1849.	1849.	1850.
1844.	1848.	1841.	1826.?	1840.	1846.	1850.?	1849.	1850.?	1846.	1849.	1848.
1840.	1847.	1835.?	1820.?	1837.	1843.	1848.?	1843.	1846.?	1844.	1846.	1846.
1837.	1844.?	1834.	1819.	1829.	1842.	1847.	1842.?	1845.?	1844.?	1844.	1845.
1837.	1839.	1833.	1818.	1828.	1842.	1844.	1837.	1844.	1844.	1843.	1843.
1836.	1836.	1832.	1812.	1827.	1841.	1843.	1836.	1843.	1843.	1842.	1842.
1835.?	1830.	1822.	1812.	1826.	1840.	1842.	1835.	1831.	1843.	1841.	1841.
1835.	1827.	1821.?	1810.	1825.?	1838.	1841.	1829.	1829.	1842.	1841.	1836.
1825.?	1826.	1816.	1810.?	1825.?	1834.	1840.	1827.?	1827.?	1840.	1839.	1834.
1824.	1825.	1813.	1808.	1820.	1828.	1837.	1827.	1827.?	1838.	1839.	1834.
1796.	1824.	1813.	1804.	1815.	1822.	1835.	1826.	1826.	1829,	1836.?	1833.
1785.?	1818.	1811.	1803.	1808.	1822.?	1835.	1824.?	1825.	1827.	1835.	1821.

							1823.	1822.	1824.	1834.?	1813.
1697.	1815.	1806.	1799.	1803.	1821.	1831.	1822.?	1822.	1819.	1833.	1807.
1690.	1814.	1805.	1795.	1791.	1819.	1831.?	1822.	1822.	1818.	1833.	1803.
1622.	1796.	1804.	1782.	1760.	1818.	1829.?	1819.	1814.	1815.	1833.	1798.
1583.	1785.	1798.	1761.	1760.	1809.	1825.?	1818.	1813.	1803.	1829.?	1795.
1572.?	1777.?	1796.	1715.	1751.	1805.	1825.?	1816.	1813.?	1802.	1822.	1741.
1570.	1772.	1731.	1692.	1737.	1794.	1820.	1816.?	1808.	1787.	1820.	1737.
1496.	1750.?	1719.	1628.	1698.	1769.	1816.?	1813.?	1806.?	1770.	1820.?	1704.
1328.	1740.	1718.?	1620.	1680.	1762.	1814.	1812.	1802.?	1765.	1819.	1642.
	1671.	1711.	1540.?	1677.	1739.	1811.	1810.	1798.	1750.	1814.	1636.
	1647.	1676.	1093.?	1580.	1723.	1810.	1778.	1777.	1738.?	1811.	1586.
		1654.		1561.	1722.	1803.	1776.?	1775.	1725.	1810.	1560.?
		1636.		1552.	1706.	1790.	1783.	1768.	1714.	1810.	
		1596.		1520.	1668.	1782.	1738.?	1753.	1704.	1805.	
		1583.		1379.	1591.	1771.	1650.	1654.	1689.	1775.	
		1564.?		1164.	1540.	1766.	1647.	1603.	1674.	1768.	
		1491.			1528.	1764.	1642.	1511.	1634.	1762.	
		1138.?			1186.	1755.	1618.	1002.?	1304.	1758.	
						1753.	1021.?			1742.	
						1727.				1637.	
						1725.				1627.	
						1635.				1623.	
						1581.				1618.	
						1565.				1567.	
						1249.				1557.	
						1198.?				1548.	
						1029.				1492.	
						1021.?				1491.	

This Table to be read thus: in *January* no aërolitic fall or detonating meteor seen in 1860 or 1859; there was one in 1858, then none back to 1851, in which month two were reported, but upon which some suspicion rests; two were seen in 1850, and so on for January and all the other months.

TABLE II.

Showing the number of Aërolitic Falls and Detonating Meteors in each Month, and total number for each Year, from A.D. 1860 back to A.D. 1800.

Year.	Month un-known.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Totals.
1860.	...	......	......	......	......	*	½	½**	*	......	......	......	......	5
1859.	...	......	......	*	......	......	......	......	**	½*½	......	**	......	7
1858.	...	*	......	......	......	*	......	......	*½	½*	......	......	*	6
1857.	...	......	**	......	*	......	......	......	½	......	**	......	**	7½
1856.	...	......	**½	......	½	......	......	*	......	*	*	*	......	7
1855.	...	......	......	......	......	**	*	......	*	......	......	......	......	4
1854.	...	......	......	*	......	......	......	*½	......	*	½	*	......	5
1853.	...	......	*	½*	......	......	......	......	......	......	*	......	*	4½
1852.	*½	*	......	......	......	......	......	*	......	*	**	......	½*	8
1851.	...	½½	*	......	*	......	......	*	......	......	......	*	½	5½
1850.	...	**	*	......	½	*	****	½	......	½	......	*	*	11½
1849.	...	......	......	*	......	......	*	......	**	......	*	***	......	8
1848.	...	......	*	......	......	*	......	½	......	......	......	......	*	3½
1847.	...	......	*	*	......	......	......	*	......	......	......	......	......	3
1846.	½	......	......	......	......	*	**	......	......	½	*	*	*	7
1845.	...	½*	......	......	......	......	......	......	......	*	......	......	*	3½
1844.	...	*	½	......	*	......	......	*	......	*	**½	*	......	8
1843.	...	......	......	*	......	......	*	*	*	*	**	*	*	9
1842.	...	......	......	......	*	......	**	*	½	......	*	*	*	7½
1841.	...	......	......	**	......	......	*	*	......	......	......	**	*	7
1840.	...	*	......	......	......	**	*	*	......	......	*	......	......	6
1839.	...	......	*	......	......	......	......	......	......	......	......	**	......	3
1838.	...	......	......	......	*	......	*	......	......	......	*	......	......	3
1837.	...	**	......	......	½	*	......	*	*	......	......	......	......	5½
1836.	½	*	*	......	......	......	......	......	*	......	......	½	*	4½
1835.	...	½*	......	½	......	......	......	**	*	......	......	*	......	6

[illegible]	...	......	......	*	......	......	......	½	......	......	......	***	*	5½
1832.	...	......	......	*	......	......	......	......	......	......	......	......	......	1
1831.	...	......	......	......	......	......	......	*½	......	*	......	......	......	2½
1830.	...	......	*	......	......	......	......	......	......	......	......	......	......	1
1829.	...	......	......	......	......	*	......	½	*	*	*	½	......	5
1828.	...	......	......	......	......	*	*	......	......	......	......	......	......	2
1827.	...	......	*	......	......	*	......	......	*½	½½	*	......	......	5½
1826.	½	......	*	......	½	*	......	......	*	*	......	......	......	5
1825.	...	½	*	......	......	½½	......	½½	......	*	......	......	......	4½
1824.	...	*	*	......	......	......	......	......	½	......	*	......	......	3½
1823.	...	......	......	......	......	......	......	......	*	......	......	......	......	1
1822.	...	......	......	*	......	......	½**	......	½*	***	......	*	......	9
1821.	...	......	......	½	......	......	*	......	......	......	......	......	*	2½
1820.	...	......	......	......	½	*	......	*	......	......	......	*½	......	4
1819.	...	......	......	......	*	......	*	......	*	......	*	*	......	5
1818.	...	......	**	......	*	......	*	......	*	......	*	......	......	6
1817.	...	......	......	......	......	......	......	......	......	......	......	......	......	0
1816.	...	......	......	*	......	......	......	½	*½	......	......	......	......	3
1815.	½	......	*	......	......	*	......	......	......	......	*	......	......	3½
1814.	...	......	*	......	......	......	......	*	......	*	......	*	......	4
1813.	...	......	......	**	......	......	......	......	½	½*	......	......	*	5
1812.	½	......	......	......	**	......	......	......	*	......	......	......	......	3½
1811.	...	......	......	*	......	......	......	*	......	......	......	*	......	3
1810.	...	......	......	......	*½	......	......	*	*	......	......	**	......	5½
1809.	...	......	......	......	......	......	*	......	......	......	......	......	......	1
1808.	**	......	......	......	*	*	......	......	......	*	......	......	......	5
1807.	...	......	......	*	......	......	......	......	......	......	......	......	*	2
1806.	...	......	......	*	......	*	......	......	......	½	......	......	......	2½
1805.	...	......	......	*	......	......	*	......	......	......	......	*	......	3
1804.	...	......	......	*	*	......	......	......	......	......	......	......	......	2
1803.	...	......	......	......	*	*	......	*	......	......	*	......	*	5
1802.	*	......	......	......	......	......	......	......	......	½	*	......	......	2½
1801.	...	......	......	......	......	......	......	......	......	......	......	......	......	0
1800.	...	......	......	......	*	......	......	......	......	......	......	......	......	1

TABLE III.

Distribution of Classes A, B, and C for Day and Month.

Day of Month.	January.			February.			March.			April.			May.			June.			July.			August.			September.			October.			November.			December.		
	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.
1	...	1	3	...	...	2	1	2	2	2	2	1	1	...	1	...	...	4	...	...	1	1	...	2	...	3	4	3	2	3	...	1	2	...	...	...
2	...	2	6	...	...	2	1	...	3	...	...	1	...	1	4	1	...	2	...	...	...	...	1	2	...	1	5	...	1½	1	...	...	5	...	...	6
3	...	...	...	1	1	1	...	...	2	...	...	2	...	...	1	2	3	1	3	1	1	...	...	7	1	...	...	1	...	3	...	...	4	1	1	1
4	1	...	2	...	...	2	...	...	2	...	...	5	...	1	4	1½	...	2	3½	½	1	2	½	1	3	...	4	...	1	3	...	...	7	...	...	1
5	...	1	...	...	...	2	½	...	1	2	½	...	1	...	1	1	1	...	½	...	1	1½	...	5	2	...	3	1	2	1	3	...	1	...	3	3
6	...	...	2	...	1	3	2½	...	4	...	...	2	...	...	2	1	1	2	...	½	...	1	1	4	...	½	4	1	...	2	...	1	4	...	...	1
7	...	...	3	...	...	2	...	1	2	...	...	...	...	...	1	3	...	3	1	1	...	3	1	4	1	...	7	...	...	3	1	...	4	...	...	3
8	...	1½	4	...	1	...	1½	...	4	...	1	2	2	...	1	...	...	...	2	1	2	...	...	2	...	...	2	1	1	3	...	...	3	1	...	6
9	2½	1	4	...	½	1	...	...	3	1	1	2	2	1½	...	2	...	2	...	...	1	...	...	5	1	...	...	...	1	2	...	2	6	1	...	5
10	1½	1	3	2	1	4	...	1	2	1½	...	2	...	1	3	...	1	2	...	...	1	1	...	5	2	...	7	1	...	...	...	...	2	...	½	2
11	...	...	1	...	2	3	...	...	2	1	...	4	1	...	3	...	1	1	...	...	3	1	1½	4	...	1	4	1	...	3	...	2	5	1	2	5
12	...	1	1	...	...	1	3	...	...	...	...	2	½	...	2	3	1	1	1	...	3	...	...	3	...	...	1	1	...	3	1	2	2	1	...	4
13	1	...	3	1	...	1	1	...	3	1	...	2	1½	1	...	1	...	1	½	...	5	...	1	3	2	1	4	3	...	4	1	2	8	4	...	4
14	...	...	...	...	...	1	1	...	1	...	...	2	...	1	1	1	...	1	1½	...	2	...	...	2	1	1	1	1	...	4	...	...	4	1	...	3
15	2	...	2	2	1	...	1	...	3	2½	...	2	...	...	3	1	...	1	2	...	...	1	½	4	½	1	3	...	...	4	1	1	1	1	1	3
16	1	2	3	...	1	...	...	1	1	...	...	1	...	...	1	1	1	1	½	1	1	...	...	3	1	...	1	...	...	1	...	...	2	...	...	3
17	...	...	...	...	...	2	1	1	2	2	...	2	3	...	...	...	...	3	1½	3	5	...	...	3	...	1	...	...	1	4	1	1	4	½	1½	3
18	1	...	1	3	1	2	...	1	2	1	...	3	1	...	3	...	...	2	1	½	2	...	1½	2	...	...	2	1	...	4	...	1	2	...	...	3
19	...	...	2	1	1	2	1	2½	2	1	...	2	4	...	3	...	...	4	...	...	1	...	...	2	1	1	2	...	1	3	½	...	7	...	...	3
20	...	½	3	...	½	...	...	...	2	½	...	...	1	...	1	2	...	2	...	3	3	...	1	3	...	...	2	...	...	2	1	2	3	...	...	1
21	...	...	5	...	...	2	...	2	...	...	...	2	1	2	1	...	...	1	...	1	2	...	...	...	...	...	3	1	...	1	...	1	1	...	2	6
22	[illegible]	[illegible]	[illegible]	...	1	3	2	...	1	...	...	1	1	...	2	1	1	3	1	...	2	...	...	[illegible]	...	...	5	...	1	2	...	½	3	...	...	4
23	[illegible]	½	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	...	...	1	...	...	2	[illegible]	...	3	...	½	5	...	½	2	...	2	4	2	...	1	...	...	7

25	...	...	2	...	2	1	2	...	1	...	...	...	...	...	...	...	1	...	...	...	...	...	...	4	...	½	2	1	...	1	1	1	1	...	...	3
26	...	...	2	...	...	3	...	...	2	2	...	1	2	...	1	...	...	1	3	...	1	...	1	3	...	...	1	...	...	3	...	...	2	2	...	1
27	...	1	4	2	...	...	...	...	1	...	...	2	1	...	2	...	...	...	...	...	2	...	...	...	...	...	1	1	1	3	1	1	1	...	...	3
28	1	...	3	1	...	1	1	...	3	½	...	2	1	...	1	...	...	2	1	...	1	...	...	2	...	...	3	...	1	2	1	1	2	2	...	...
29	...	...	...	...	...	...	...	...	4	1	...	4	...	...	1	...	1	3	...	...	6	...	...	...	1	...	3	...	...	3	1	½	4	...	...	3
30	...	...	2	...	...	...	1	...	2	1	...	4	...	...	1	1	...	...	...	...	5	...	½	4	...	...	2	1	...	...	3	...	2	...	...	5
31	...	...	1	...	...	...	...	1	2	...	...	1	...	...	2	...	...	...	...	...	2	...	...	1	...	...	...	1	...	2	...	...	...	...	...	1
?	1	...	...	...	½	1	...	...	2	...	1	...	4	½	2	2½	...	1	3	1	2	7	2½	2	1	1½	5	...	1	2	3	1½	5	½	1	2

1860.

Analysis of Tables I. and II.

Maximum Years.		Remarks.	Minimum Years.	
Observed.	Calculated.		Calculated.	Observed.
1857.	1859.		1855.	1854.
1850.	1851.		1847.	1847.
1843.	1843.	A supposed interval of eight years in minimum & maximum frequency.	1839.	1839.
1835.	1835.		1831.	1830 to 1832.
1827.	1827.		1823.	1823.
1818 to 1822.	1819.		1815.	1817.
1810.	1811.		1807.	1809.
1803.	1803.		1799.	1799 to 1801.
1795 or 1796.	1795.		1791.	1792 to 1793.

TABLE IV.

Bolides: Classes C and D. Number observed each Day and Month.

Day of Month.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day of Month.
1	4	4	6	3	2	5	1	4	4	5	5	3	1
2	9	2	3	3	6	3	2	4	7	3	6	6	2
3	1	5	3	3	1	1	2	12	2	6	5	3	3
4	2	3	1	5	5	2	2	3	6	6	8	2	4
5	...	2	2	...	1	1	2	7	4	1	3	4	5
6	3	6	5	5	2	4	2	4	5	6	6	3	6
7	2	9	3	...	4	3	...	8	7	4	5	3	7
8	4	3	5	4	2	1	3	6	4	2	9	11	8
9	4	2	3	3	2	4	3	10	1	2	11	6	9
10	5	5	3	3	4	2	2	15	7	4	3	3	10
11	6	4	1	7	4	1	9	7	4	3	10	12	11
12	4	2	2	4	2	5	6	15	1	3	8	4	12
13	5	2	3	3	2	4	5	7	4	6	13	6	13
14	1	2	1	6	1	3	3	3	1	5	10	3	14
15	4	1	5	2	5	1	2	6	3	4	7	3	15
16	3	...	1	2	3	3	1	6	2	3	6	5	16
17	1	4	2	3	2	4	6	3	1	6	5	3	17
18	3	4	3	6	5	2	3	6	3	5	4	4	18
19	5	5	4	6	4	4	2	5	3	4	13	3	19
20	5	3	4	...	3	2	5	5	5	6	4	2	20
21	6	4	1	1	2	2	3	1	3	1	2	9	21
22	3	4	1	...	3	4	2	7	7	6	4	4	22
23	3	4	2	...	2	3	5	5	1	6	5	1	23

24	[illegible]	2	2	[illegible]	[illegible]	1	4	...	[illegible]	[illegible]	1	[illegible]	24
25	3	1	1	1	...	...	1	5	3	3	1	4	25
26	5	3	3	1	3	1	1	6	...	4	3	...	26
27	4	2	1	3	2	3	3	1	3	5	4	3	27
28	5	2	4	3	...	4	2	4	6	3	5	5	28
29	3	1	4	4	4	3	10	4	2	4	7	5	29
30	5	...	4	4	1	2	7	4	4	4	4	6	30
31	2	...	3	...	5	...	4	2	...	3	...	2	31
? ?	1	3	1	...	2	1	2	3	5	2	4	3	? ?

TABLE V.

Aërolitic Epochs common to Meteor Epochs.	Aërolitic Epochs distinct from Meteor Epochs.	Times of fewest Aërolites.	Times of most Aërolites.	
January 8 to 13 ?.	February 10 to 19 ?.	January 19 to February 7.	January 8 to 10.	August 4 to 7.
July 12 to 22.	March 14 to 24.	April 21 to 25.	February 10 to 19.	September 1 to 16.
August 4 to 7.	May 8 to 22.	April 29 to May 7.	March 12 to 25.	October 1 to 7.
September 1 to 15.	June 3 to 7.	August 21 to 31.	April 8 to 20.	November 5 to 13.
October 1 to 6 ?.	July 3 to 8.	September 17 to 30.	May 8 to 22.	November 17 to 30.
November 5 to 13.		November 31 to December 10.	June 2 to 16.	December 11 to 17.
November 27 to 30.		December 18 to 25.		
December 11 to 18.		December 30 to January 7.		

TABLE VI.

Aërolites; Detonating Meteors and Bolides, with number for each Month.

Months.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.	Monthly Average.
Stone- and Iron-falls: A	12	13	20½	20	28	25	28	18½	17½	20	21½	16	240	20
Detonating Meteors: B	12½	15½	13½	5½	9	12	13½	13½	14	16½	23½	13½	162½	13½
Total aërolitic	24½	28½	34	25½	37	37	41½	32	31½	36½	45	29½	402½	33½
Bolides: Class C	66	47	65	55	51	49	61	92	85	79	98	91	839	70
Ditto: Class D	51	47	22	34	36	30	44	87	26	54	83	43	557	46
Totals: C and D	117	94	87	89	87	79	105	179	111	133	181	134	1396	116

TABLE VII.

Analysis of Table VI.

Class.	Solstitial, or 1st six months.	Solstitial, or 2nd six months.	Six Summer months.	Six Winter months.	Dec. and Jan. Aphelion.	June and July. Perihelion.
Stone- and Iron-falls: A	118½	121½	137	103	28½	53
Detonating Meteors: B	68	94½	67½	95	26	25½
Total Aërolitic	186½	216	204½	198	54½	78½
Bolides: C and D	553	843	650	746	251	184
Totals	739½	1059	854½	944	305½	262½

TABLE VIII.

Month.	A.D. 1 to 1700.		A.D. 1700 to 1800.		A.D. 1800 to 1860.		Totals.	
	A and B.	C.	A and B.	C.	A and B.	C.	A and B.	C.
January	7½	7	3½	3	13½	56	24½	66
February	2	8	5½	5	21	34	28½	47
March	7½	15	5	12	21½	38	34	65
April	4	11	4½	9	17	35	25½	55
May	12	9	5	7	20	38	37	51
June	6	4	7	3	24	42	37	49
July	6½	5	9	13	26	43	41½	61
August	4½	5	2½	17	25	70	32	92
September	3½	10	5	14	23	61	31½	85
October	6	8	6½	13	24	58	36½	79
November	9	7	5	15	31	76	45	98
December	4½	7	5	11	20½	73	29½	91

TABLE IX.

Hours. A.M.	Stone- or Iron-falls.	Detonating Meteors.	Totals.	Hours. P.M.	Stone- or Iron-falls.	Detonating Meteors.	Totals.
12 to 1	...	...	...	12 to 1	7	1	8
1 to 2	...	2	2	1 to 2	6	1	7
2 to 3	2	1	3	2 to 3	11	5	16
3 to 4	...	2	2	3 to 4	20	2	22
4 to 5	...	1	1	4 to 5	14	4	18
5 to 6	1	...	1	5 to 6	14	3	17
6 to 7	3	1	4	6 to 7	8	4	12
7 to 8	3	2	5	7 to 8	6	3	9
8 to 9	7	2	9	8 to 9	10	6	16
9 to 10	7	1	8	9 to 10	4	12	16
10 to 11	4	2	6	10 to 11	...	2	2
11 to 12	6	4	10	11 to 12	2	1	3
Totals, A.M....	33	18	51	Totals, P.M....	102	44	146

Analysis of Table IX.

Time of Observations.	Stone- and Iron-falls.	Detonating Meteors.	Totals.
Day: 6 A.M. to 6 P.M.	102	28	130
Night: 6 P.M. to 6 A.M.	33	34	67
Midnight to Noon	33	18	51
Noon to Midnight	102	44	146
Forenoon: 6 A.M. to Noon	30	12	42
Afternoon: Noon to 6 P.M.	72	16	88

TABLE X.

Showing the direction of Aërolitic and first-class Meteors, A, B, and C.

Months.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Totals.
No. of Observations	23	23	22	21	22	26	21	33	39	26	33	29	308
With Easterly direction	14	13	8	5	6	8	7	11	19	17	12	10	130
With Westerly direction	6	10	10	13	13	7	12	15	15	7	20	11	139
With Northerly direction	6	11	7	7	9	9	9	14	13	7	9	10	111
With Southerly direction	13	8	4	8	6	11	3	13	11	10	11	12	110
Average or prevailing direction for each month.	S.E.	E.N.E.	N.N.W.	W.	N.W.	S.?	N.W.	W.?	E.N.E.	E.S.E.	W.N.W.	S.?	W.?

REMARKS.

1. While there appear to be eight yearly *maximum* and *minimum* aërolitic periods for the years generally, there are likewise some indications of other periods for some of the months taken separately.

Some months may have major or longer periods of *maximum*, as November, which perhaps has one of about 70 years (though for the sporadic showers, according to Herrick, one of 33 years, in which case the numbers of shooting stars should now be again on the increase, so as to culminate in 1866). January has also probably a long or irregular period, as regards classes A and B. Of late years the numbers for December and January have evidently been on the increase, and especially as regards the former month, and this as regards all classes; and the eighth to the seventeenth days appears to embrace a time favourable to a considerable increase over the average for the month. Tables I., II., III., and IV.

2. The proportionate numbers of each class appear to have varied at different times for the different months. Table VIII.

3. There appear to be aërolitic and meteor epochs both distinct from and common to each other. A proximate attempt has been made to show some of these in Table V.; perhaps some of these are more apparent than real; but the subject is worth consideration.

4. While the aërolitic class, A and B, in its total is under the average for August, which is the principal and most constant month for an abundance of sporadic meteors, it is over the average for November, likewise a month noted for an abundant display of meteors and shooting stars; and while there is an increase over the average of detonating meteors (though not of recorded Stone-falls), from the 9th to the 13th of November, *i. e.* precisely during the regular periodical appearance, it is not a little singular that the August aërolitic period, if it may be so called, precedes by several days the usual period of greatest abundance of the shooting stars; one being August 4 to 7, both inclusive, and the other August 9 to 12. See Table III.

5. The decided preponderance of aërolitic phenomena, alluded to in the Report as occurring in the afternoon, as compared with the forenoon, will be seen clearly given in Table IX.

6. As regards the observed direction of aërolitic and first-class meteors, there would seem not to be any very great tendency one way or the other; it would have been natural to have expected a much more decided leaning to a Westerly direction. The sudden change from an Easterly direction in September and October (about the time of the autumnal equinox), to a Westerly direction in November, is remarkable, and calls for especial notice.

7. The considerable increase of aërolitic falls and meteors for the months of June and July over those of December and January has been previously alluded to in the Report itself. That more detonating meteors in proportion to Stone-falls should be recorded during the winter months than during the summer months, is precisely what might have been expected, and the reverse holds equally good. Tables VI. and VII.

8. Taking the entire year, there is a much greater tendency towards equality of distribution in the aërolitic class than is the case with sporadic shooting stars and the smaller meteors; indeed, were it not for the excess in November (an excess common to every class apparently), the numbers of the former (A and B) would be about equal for the first as for the second half of the year.

CORRIGENDA ET ADDENDA.

Page 53, line 22 from top: *for* "1596" *read* 1596.*.
Page 59, line 18 from top: *for* "Sarthé" *read* Sarthe.
Page 62, 1804. Apr. 15. Geneva. fireball: *add*, s. to N.; *also*, followed by a train of smaller balls.
Page 64, line 18 from top: *for* "Aug. 10" *read* early part of Aug.
Page 64, line 12 from bottom: *for* "Iron-fall" *read* Stone-fall.
Page 65, line 7 from bottom: fireball at Göttingen; *add*, followed by many smaller balls.
Page 67, top line: *for* "1819. June 13. Jonsac" *read* and *add*, 1819.* June 13. Jonsac, Charente, &c. &c.
Page 70, line 5 from top: Görlitz; fireball; *add* aërolitic ?.
Page 71, line 11 from bottom: *replace the* (*) before May 12, by a (?).
Page 71, line 12 from bottom: *insert the* (*) before May 19. Ekaterinosloff, &c.
Page 72, line 6 from top: *read* February 27 or February 16.
Page 72, line 11 from bottom of Notes: *for* "Summer co." *read* Sumner co.
Page 73, line 3 from top: *add* Vouillé near "Poitiers."
Page 74, line 21 from top: *for* "Okaninak" *read* Okaninah.
Page 82, line 6 from top: *for* "Nuremberg" *read* Nurenberg.
Page 92, after line 5 from top: *insert*, Apr. 12. Berne. Fireball.
Page 94, line 10 from top: *for* "Columb" *read* Columbus.
Page 96, after line 16 from bottom: *insert* 1860.* Feb. 2. Alessandria, Piedmont. A stone-fall. Also omitted in the Tables.

Report on the Theory of Numbers.—Part II. *By* H. J. STEPHEN SMITH, *M.A., F.R.S., Savilian Professor of Geometry, Oxford.*

39. *Residues of the Higher Powers. Researches of Jacobi.*—The principles which have sufficed for the determination of the laws of reciprocity affecting quadratic, cubic, biquadratic, and sextic residues, are found to be inadequate when we come to residues of the 5th, 7th, or higher powers. This was early observed by Jacobi, when, after his investigations of the cubic and biquadratic theorems, he turned his attention to residues of the 5th, 8th, and 12th powers*. It was evident, from a comparison of the cubic and biquadratic theories, that in the investigation of the laws of reciprocity the ordinary prime numbers of arithmetic must be replaced by certain factors of those prime numbers composed of roots of unity; and Jacobi, in the note just referred to, has indicated very clearly the nature of those factors in the case of the 5th, 8th, and 12th powers respectively. He ascertained that the two complex factors composed of 5th roots of unity into which every prime number of the form $5n+1$ is resoluble by virtue of Theorem IV. of art. 30 of this Report, are not prime numbers, *i. e.* are each capable of decomposition into the product of two similar complex numbers; so that every (real) prime number of the form $5n+1$ is to be regarded as the product of *four* conjugate complex factors; and these factors are precisely the complex primes which we have to consider in the theory of quintic residues, in the place of the real primes they divide. To this we may add that primes of the forms $5n\pm2$ continue primes in the complex theory; while those of the form $5n-1$ resolve themselves into *two* complex prime factors. Thus

$$7=7;\quad 11=(2+\alpha)(2+\alpha^2)(2+\alpha^3)(2+\alpha^4)^{*};\quad 13=13;$$

$$19=\big(4-3(\alpha+\alpha^4)\big)\big(4-3(\alpha^2+\alpha^3)\big);\quad 29=\big(5-(\alpha+\alpha^4)\big)\big(5-(\alpha^2+\alpha^3)\big);$$

$$31=(2-\alpha)(2-\alpha^2)(2-\alpha^3)(2-\alpha^4)^{\dagger},\ \&c.,$$

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* See a note communicated by him to the Berlin Academy on May 16, 1839, in the 'Monatsberichte' for that year, or in Crelle, vol. xix. p. 314, or Liouville, vol. viii. p. 268, in which, however, he implies that he had not as yet obtained a definitive result; nor does he seem at any subsequent period to have succeeded in completing this investigation.

$^{*} = (5+2(\alpha+\alpha^4))(5+2(\alpha^2+\alpha^3))$ $\quad$ $^{\dagger} = (5-2(\alpha+\alpha^4))(5-2(\alpha^2+\alpha^3))$

where α is an imaginary 5th root of unity. Precisely similar remarks apply to the theories of residues of 8th and 12th powers,—real primes of the forms $8n+1$, $12n+1$, resolving themselves into four factors composed of 8th and 12th roots of unity respectively. By considerations similar to those previously employed by him in the case of biquadratic and cubic residues, Jacobi succeeded in demonstrating (though he has not enunciated) the formulæ of reciprocity affecting those powers for the particular case in which one of the two primes compared is a real number. But it would seem that he never obtained the law of reciprocity for the general case of any two complex primes; and indeed, for a reason which will afterwards appear, it was hardly possible that he should do so, so long as he confined himself to the consideration of those complex numbers which present themselves in the theory of the division of the circle. No less unsuccessful were the efforts of Eisenstein to obtain the formulæ relating to 8th powers, by an extension of the elliptical properties employed by him in his later proofs of the biquadratic theorem *. It does not appear that any subsequent writer has occupied himself with these special theories; while, on the other hand, the theory of complex numbers composed with roots of unity of which the exponent is any prime, has been the subject of an important series of investigations by MM. Dirichlet and Kummer, and has led the latter eminent mathematician to the discovery and demonstration of the law of reciprocity, which holds for all powers of which the exponent is a prime number not included in a certain exceptional class.

40. *Necessity for the Introduction of Ideal Primes.*—The fundamental proposition of ordinary arithmetic, that if two numbers have each of them no common divisor with a third number, their product has no common divisor with that third number, is, as we have seen, applicable to complex numbers formed with 3rd or 4th roots of unity, because it is demonstrable that Euclid's theory of the greatest common divisor is applicable in each of those cases. With complex numbers of higher orders this is no longer the case; and it is accordingly found that the arithmetical consequences of Euclid's process, which are of so much importance in the simpler cases, cease to exist in the general theory. In particular, the elementary theorem, that a number can be decomposed into prime factors in one way only, ceases to exist for complex numbers composed of 23rd † or higher roots of unity—if, at least (in the case of complex as of real numbers), we understand by a prime factor, a factor which cannot itself be decomposed into simpler factors ‡. It appears, therefore, that in the higher complex theories, a number is not necessarily a prime number simply because it cannot be resolved into complex factors. But by the introduction of a new arithmetical conception—that of ideal prime factors—M. Kummer has shown that the analogy with the arithmetic of common numbers is completely restored. Some preliminary observations are, however, necessary to explain clearly in what this conception consists.

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* See M. Kummer, "Ueber die Allgemeinen Reciprocitätsgesetze," p. 27, in the Memoirs of the Berlin Academy for 1859.

† For complex numbers composed with 5th or 7th roots of unity, the theorem still exists; for 23 and higher primes it certainly fails; whether it exists or not for 11, 13, 17, and 19, has not been definitely stated by M. Kummer (see below, Art. 50).

‡ "Maxime dolendum videtur" (so said M. Kummer in 1844) "quod hæc numerorum realium virtus, ut in factores primos dissolvi possint, qui pro eodem numero semper iidem sint, non eadem est numerorum complexorum, quæ si esset, tota hæc doctrina, quæ magnis adhuc difficultatibus premitur, facile absolvi et ad finem perduci posset." (See his Dissertation in Liouville's Journal, vol. xii. p. 202.) In the following year he was already able to withdraw this expression of regret.

41. *Elementary Definitions relating to Complex Numbers.*—Let λ be a prime number, and α a root of the equation $\frac{\alpha^\lambda-1}{\alpha-1}=0$; then any expression of the form

$$F(\alpha)=a_0+a_1\alpha+a_2\alpha^2+\ldots.+a_{\lambda-2}\alpha^{\lambda-2} \quad . \quad . \quad . \quad . \quad (A.)$$

in which $a_0, a_1, a_2, \ldots. a_{\lambda-2}$, denote real integers, is called a complex integral number. To this form every rational and integral function of α can always be reduced; and it follows, from the irreducibility of the equation $\frac{\alpha^\lambda-1}{\alpha-1}=0$, that the same complex number cannot be expressed in this reduced form in two different ways. The *norm* of $F(\alpha)$ is the real integer obtained by forming the product of all the $\lambda-1$ values of $F(\alpha)$, so that

$$N.F(\alpha)=N.F(\alpha^2)=\ldots=N.F(\alpha^{\lambda-1})=F(\alpha).F(\alpha^2).F(\alpha^3)\ldots F(\alpha^{\lambda-1}).$$

The operations of addition, subtraction and multiplication present no peculiarity in the case of these complex numbers; by the introduction of the norm, the division of one complex number by another is reduced to the case in which the divisor is a real integer. Thus

$$\frac{f(\alpha)}{F(\alpha)}=\frac{f(\alpha)F(\alpha^2)F(\alpha^3)\ldots.F(\alpha^{\lambda-1})}{N.F(\alpha)};$$

and $f(\alpha)$ is said to be divisible by $F(\alpha)$ when every coefficient in the product $f(\alpha)F(\alpha^2)F(\alpha^3)\ldots F(\alpha^{\lambda-1})$, developed and reduced to the form (A), is divisible by $N.F(\alpha)$. When $f(\alpha)$ is not divisible by $F(\alpha)$, it is not, in general, possible to render the norm of the remainder less than the norm of the divisor; and it is owing to this circumstance that the common rule for finding the greatest common divisor is not generally applicable to complex numbers. If, in the expression (A), we consider the numbers $a_0, a_1\ldots a_{\lambda-2}$ as indeterminates, the norm is a certain homogeneous function of order $\lambda-1$, and of $\lambda-1$ indeterminates; so that the inquiry whether a given real number is or is not resoluble into the product of $\lambda-1$ conjugate complex factors, is identical with the inquiry whether it is or is not capable of representation by a certain homogeneous form, which is, in fact, the *resultant* of the two forms

$$a_0x^{\lambda-2}+a_1x^{\lambda-3}y+\cdots+a_{\lambda-2}y^{\lambda-2},$$

and

$$x^{\lambda-1}+x^{\lambda-2}y+x^{\lambda-3}y^2+\cdots+y^{\lambda-1}.$$

The problem is considered in the former aspect by M. Kummer, in the latter by Dirichlet. The methods of Dirichlet appear to have been of extreme generality, and are as applicable to complex numbers, composed with the powers of a root of *any* irreducible equation having integral coefficients, as to the complex numbers which we have to consider here. Nevertheless, in the outline of this theory which we propose to give, we prefer to follow the course taken by M. Kummer: for Dirichlet's results have been indicated by him, for the most part, only in a very summary manner *; nor is it in any case difficult to assign to them their proper place in M. Kummer's theory; while, on the other hand, it would, perhaps, be impossible to express adequately, in any other form than that which M. Kummer has adopted, the numerous and important results (including the law of reciprocity itself) contained in the elaborate series of memoirs which he has devoted to this subject *.

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* See his notes in the Monatsberichte of the Berlin Academy for 1841, Oct. 11, p. 280; 1842, April 14, p. 93; and 1846, March 30; also a letter to M. Liouville, in Liouville's Journal, vol. v. p. 72; a note in the Comptes Rendus of the Paris Academy for 1840, vol. x. p. 286; and another in the Monatsberichte for 1847, April 15, p. 139.

42. *Complex Units.*—A complex unit is a complex number of which the norm is unity. If $\lambda=3$, there is only a finite number [six] of units included in the formula $\pm\alpha^k$. But for all higher values of λ, the number of units is infinite. Nevertheless it is always possible to assign a system of $\mu-1$ units (putting, for brevity, $\frac{1}{2}(\lambda-1)=\mu$) such that *all* units are included in the formula $\pm\alpha^k u_1^{n_1} u_2^{n_2} \dots u_{\mu-1}^{n_{\mu-1}}$; in which $u_1, u_2, u_3, \dots u_{\mu-1}$ are the assigned units, and $k, n_1, n_2, \dots n_{\mu-1}$, are real (positive or negative) integral numbers. A system of units, capable of thus representing all units whatsoever, is called a fundamental system. The existence, for every value of λ, of fundamental

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* The following is a list of M. Kummer's memoirs on complex numbers:—

1. De numeris complexis qui radicibus unitatis et numeris realibus constant, Breslau, 1844. This is an academical dissertation, addressed by the University of Breslau to that of Königsberg, on the tercentenary anniversary of the latter. It has been inserted by M. Liouville in his Journal, vol. xii. p. 185.

2. Ueber die Divisoren gewisser Formen der Zahlen, welche aus der Theorie der Kreistheilung entstehen.—Crelle, vol. xxx. p. 107.

3. Zur Theorie der Complexen Zahlen, in the Monatsberichte for March 1845, or in Crelle, vol. xxxv. p. 319.

4. Ueber die Zerlegung der aus Wurzeln der Einheit gebildeten complexen Zahlen in ihre Primfactoren.—Crelle, vol. xxxv. p. 327. The date is Sept. 1846.

5. A note addressed to M. Liouville (April 28, 1847), in Liouville's Journal, vol. xii. p. 136.

6. Bestimmung der Anzahl nicht æquivalenter Klassen für die aus λten Wurzeln der Einheit gebildeten complexen Zahlen, und die idealen Factoren derselben.—Crelle, vol. xl. p. 93.

7. Zwei besondere Untersuchungen über die Classen-Anzahl, und über die Einheiten der aus λten Wurzeln der Einheit gebildeten complexen Zahlen.—Crelle, vol. xl. p. 117. (See also the Monatsberichte of the Berlin Academy for 1847, Oct. 14, p. 305.)

8. Allgemeiner Beweis des Fermat'schen Satzes, dass die Gleichung $x^\lambda+y^\lambda=z^\lambda$ unlösbar ist, für alle diejenigen Potenz-Exponenten λ, welche ungerade Primzahlen sind, und in den Zählern der ersten $\frac{1}{2}(\lambda-3)$ Bernouillischen Zahlen als Factoren nicht vorkommen.—Crelle, vol. xl. p. 131. (See also the Monatsberichte for 1847, April 15, p. 132.) This and the two preceding memoirs are dated June 1849.

9. Recherches sur les Nombres Complexes.—Liouville, vol. xvi. p. 377. This memoir contains a very full *résumé* of the whole theory, and may be read by any one acquainted with the elements of the theory of numbers.

10. A note in the Monatsberichte of the Berlin Academy for May 27, 1850, p. 154, which contains the first enunciation of the law of reciprocity.

11. Ueber die Ergänzungssätze zu den Allgemeinen Reciprocitätsgesetzen.—Crelle, vol. xliv. p. 93 (Nov. 30, 1851), and vol. lvi. p. 270 (Dec. 1858).

12. A note on the irregularity of determinants, in the Berlin Monatsberichte for 1853, March 14, p. 194.

13. Ueber eine besondere Art aus complexen Einheiten gebildeter Ausdrücke.—Crelle, vol. l. p. 212 (Aug. 31, 1854).

14. Ueber die den Gaussischen Perioden der Kreistheilung entsprechenden Congruenzwurzeln.—Crelle, vol. liii. p. 142 (June 5, 1856).

15. Einige Sätze über die aus den Wurzeln der Gleichung $\alpha^\lambda=1$ gebildeten complexen Zahlen für den Fall, dass die Klassenzahl durch λ theilbar ist, nebst Anwendung derselben auf einen weiteren Beweis des letzten Fermat'schen Lehrsatzes.—Memoirs of the Berlin Academy for 1857, p. 41. An abstract of this memoir will be found in the Monatsberichte for 1857, May 4, p. 275.

16. Theorie der Idealen Primfactoren der complexen Zahlen, welche aus den Wurzeln der Gleichung $\omega^n=1$ gebildet sind, wenn n eine zusammengesetzte Zahl ist.—Memoirs of the Berlin Academy for 1856, p. 1.

17. Ueber die Allgemeinen Reciprocitätsgesetze unter den Resten und Nicht-Resten der Potenzen, deren Grad eine Primzahl ist.—Memoirs of the Berlin Academy for 1859, p. 20. It was read on Feb. 18, 1858, and May 5, 1859. An abstract will be found in the Monatsberichte of the former year.

A memoir by M. Kronecker (De unitatibus complexis, Berlin, 1845; it is his inaugural dissertation on taking his doctorate) connects itself naturally with the earlier memoirs of the preceding series.

systems of $\mu-1$ units may be established by means of a general proposition due to Dirichlet and relating to any irreducible equation having unity for its first coefficient, and all its coefficients integral. If, in such an equation, R be the number of real, and 2 I of imaginary roots, there always exist systems of $\mathrm{R}+\mathrm{I}-1$ fundamental units, by means of which all other units can be expressed; or, in other words, the indeterminate equation "Norm $=1$" is always resoluble in an infinite number of ways, and all its solutions can be expressed by means of $\mathrm{R}+\mathrm{I}-1$ fundamental solutions*. The demonstration of the actual existence, in every case, of these systems of fundamental units (a theorem which is, as Jacobi has said†, "un des plus importants, mais aussi un des plus épineux de la science des nombres") is of essential importance in the theory of complex numbers, and has the same relation to that theory which the solution of the Pellian equation $x^2-\mathrm{D}y^2=1$ has to the theory of quadratic forms of determinant D. It may be observed, however, that in the case which we have to consider here, that of the equation $\frac{\alpha^\lambda-1}{\alpha-1}=0$, the existence of fundamental systems of $\mu-1$ units has been demonstrated independently of Dirichlet's general theory by MM. Kronecker and Kummer‡.

If $\lambda=5$, $\alpha+\alpha^{-1}$ is the only fundamental unit; so that every unit is included in the formula

$$\pm\alpha^k(\alpha+\alpha^{-1})^n.$$

If $\lambda=7$, the complex units are included in the formula

$$\pm\alpha^k(\alpha^1+\alpha^{-1})^{n_1}(\alpha^2+\alpha^{-2})^{n_2}.$$

But for higher primes the actual calculation of a system of fundamental units involves great labour; and a method practically available for the purpose has not yet been given. It is remarkable that every unit can be rendered real (*i. e.* a function of the binary sums or *periods* $\alpha^1+\alpha^{-1}$, &c.) by multiplying it by a properly assumed power of α. We shall therefore suppose, in

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* To enunciate Dirichlet's theorem with precision, let $f(x)=0$ be the proposed equation; let $\alpha_1, \alpha_2, \ldots \alpha_n$ be its roots, and $\psi(\alpha_1), \psi(\alpha_2), \ldots \psi(\alpha_n)$ a system of n conjugate units. If the analytical modulus of every one of the quantities $\psi(\alpha_1), \psi(\alpha_2), \ldots \psi(\alpha_n)$ be unity, the system of units is an isolated or *singular* system. The number of singular systems (if any such exist) is always finite, whence it is easy to infer that the units they comprise are simply roots of unity. For if $\psi(\alpha)$ be a singular unit, its powers are evidently also singular units, and therefore cannot be all different from one another; *i. e.* $\psi(\alpha)$ is a root of unity. If $f(x)$ be of an uneven order, there are no singular units; if $f(x)$ be of an even order, -1 is a singular unit; and if $f(x)=0$ have any real roots, it is the only singular unit; whereas if all the roots of $f(x)=0$ be imaginary, other singular units may in special cases exist. Thus the equation $\frac{x^\lambda-1}{x-1}=0$ has $2(\lambda-1)$ singular units included in the formula $\pm\alpha^k$. Admitting this definition of singular units, we may enunciate Dirichlet's theorem as follows:—a system of h units $[h=\mathrm{I}+\mathrm{R}-1]$, $e_1(\alpha), e_2(\alpha), \ldots e_h(\alpha)$, composed with any root α, can always be assigned such that every unit composed with the same root can be represented (and in one way only) by the formula

$$\omega \,.\, e_1(\alpha)^{n_1} . e_2(\alpha)^{n_2} . e_3(\alpha)^{n_3} \ldots . e_h(\alpha)^{n_h},$$

where $n_1, n_2, \ldots n_h$ are positive or negative integral numbers and ω is unity, or some one of the singular units composed with α.

The principles on which the demonstration of this theorem depends are very briefly indicated in the notes presented by Dirichlet to the Berlin Academy in 1841, 1842, and 1846.

† Crelle's Journal, vol. xl. p. 312.

‡ See Kronecker, De unitatibus complexis, pars altera; and Kummer, in Liouville's Journal, vol. xvi. p. 383.

what follows, that the units of which we speak have been thus reduced to a real form.

For all values of λ greater than 5, the number of systems of fundamental units is infinite. For if $u_1, u_2, \ldots u_{\mu-1}$ still represent a system of fundamental units, it is evident that the system $E_1, E_2, \ldots E_{\mu-1}$, defined by the equations

$$\left.\begin{array}{l} E_1 \;\;\; = u_1^{(1,1)} \;\; u_2^{(1,2)} \;\; \ldots\ldots \times u_{\mu-1}^{(1,\mu-1)}, \\ E_2 \;\;\; = u_1^{(2,1)} \;\; u_2^{(2,2)} \;\; \ldots\ldots \;\; u_{\mu-1}^{(2,\mu-1)}, \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ E_{\mu-1} = u_1^{(\mu-1,1)} u_2^{(\mu-1,2)} \ldots\ldots \;\; u_{\mu-1}^{(\mu-1,\mu-1)}, \end{array}\right\} \ldots \quad (A.)$$

is also a fundamental system, if the indices (1, 1), &c. be integral numbers, and if the determinant $\Sigma \pm (1, 1)(2, 2) \ldots . (\mu-1, \mu-1)$ be equal to unity. And conversely, every system of fundamental units will be represented by the equations (A.), if in them we assign to the indices (1, 1), (2, 2), &c. all systems of integral values in succession consistent with the condition $\Sigma \pm (1,1)(2,2)(3,3) \ldots (\mu-1, \mu-1) = \pm 1$; so that a single system of fundamental units represents to us all possible systems.

We shall also have occasion to allude to independent systems of units. A system of $\mu-1$ units, $u_1, u_2, \ldots u_{\mu-1}$, is said to be independent when it is impossible to satisfy the equation

$$u_1^{n_1} u_2^{n_2} u_3^{n_3} \ldots u_{\mu-1}^{n_{\mu-1}} = 1,$$

whatever integral values are assigned to the indices $n_1, n_2, n_3, \ldots n_{\mu-1}$. The equations (A.) will represent all possible systems of independent units, if we suppose that in them the indices (1, 1), (2, 2), (3, 3) ... receive all positive and negative integral values, subject only to the condition that the determinant $\Delta = \Sigma \pm (1, 1)(2, 2) \ldots (\mu-1, \mu-1)$ must not vanish. Every system of fundamental units is also independent; but not conversely. Every unit can be represented as a product of the powers of the units of an independent system; but if the system be not also fundamental, the indices of the powers are not in general integral, but are fractions having denominators which divide Δ. Lastly, if $c_1(\alpha), c_2(\alpha), \ldots . c_{\mu-1}(\alpha)$ be a system of independent units, the logarithmic determinant

$$\begin{vmatrix} L.c_1(\alpha), & L.c_2(\alpha), & \ldots\ldots L.c_{\mu-1}(\alpha), \\ L.c_1(\alpha^{\gamma}), & L.c_2(\alpha^{\gamma}), & \ldots\ldots L.c_{\mu-1}(\alpha^{\gamma}), \\ \ldots & \ldots & \ldots \\ L.c_1(\alpha^{\gamma^{\mu-2}}), & L.c_2(\alpha^{\gamma^{\mu-2}}), & \ldots\ldots L.c_{\mu-1}(\alpha^{\gamma^{\mu-2}}), \end{vmatrix}$$

in which γ denotes a primitive root of λ, is different from zero; and conversely, if the determinant be different from zero, the system of units is independent. For all systems of fundamental units, the absolute value of the logarithmic determinant is the same; for any other independent system, its value is Δ times that least value. The quantities denoted by the symbols $L.c_1(\alpha)$, $L.c_2(\alpha)$, &c., are the arithmetical logarithms of the real units $c_1(\alpha)$, &c., taken positively.

43. *Gauss's Equations of the Periods.*—In Gauss's theory of the division of the circle, it is shown that if λ be a prime number, and if $ef = \lambda - 1$, the *e periods* of *f* roots each, that is the quantities $\eta_0, \eta_1, \eta_2 \ldots . \eta_{e-1}$, defined by the equations

$$\begin{aligned}
\eta_0 &= \alpha^{\gamma^0} + \alpha^{\gamma^e} + \alpha^{\gamma^{2e}} + \ldots\ldots + \alpha^{\gamma^{(f-1)e}}, \\
\eta_1 &= \alpha^{\gamma^1} + \alpha^{\gamma^{e+1}} + \alpha^{\gamma^{2e+1}} + \ldots\ldots + \alpha^{\gamma^{(f-1)e+1}}, \\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
\eta_{e-1} &= \alpha^{\gamma^{e-1}} + \alpha^{\gamma^{2e-1}} + \alpha^{\gamma^{3e-1}} + \ldots\ldots + \alpha^{\gamma^{fe-1}}
\end{aligned}$$

(γ still denoting a primitive root of λ), are the roots of an irreducible equation of order e having integral coefficients, which we shall symbolize by

$$F(y) = y^e + A_1 y^{e-1} + A_2 y^{e-2} + \ldots A_{e-1} y + A_e = 0$$

(see Disq. Arith. art. 346). This equation is of the kind called Abelian; that is to say, each of the e periods is a rational function of any other, in such a manner that we may establish the equations $\eta_1 = \phi(\eta_0)$, $\eta_2 = \phi(\eta_1)$, $\eta_3 = \phi(\eta_2)$, ... $\eta_0 = \phi(\eta_{e-1})$; where it is to be observed that the coefficients of the function ϕ are not in general integral. The determination of the coefficients of the equation $F(y) = 0$ may be effected, for any given prime λ, and any given divisor e of $\lambda - 1$, by methods which, however tedious, present no theoretical difficulty. Every rational and integral function of the periods can be reduced to the form $a_0\eta_0 + a_1\eta_1 + a_2\eta_2 + \ldots + a_{e-1}\eta_{e-1}$. If we combine the equation $1 + \eta_0 + \eta_1 + \eta_2 + \ldots + \eta_{e-1} = 0$ with the $e-2$ equations, by which η_0^2, η_0^3, ... η_0^{e-1} are expressed in that linear form, we may eliminate η_2, η_3, ... η_{e-1}, and shall thus obtain an equation of order e, satisfied by η_0, *i.e.* the equation of the periods, or $F(y) = 0$. This is the method proposed by Gauss (Disq. Arith. art. 346); M. Kummer, instead, forms the system of equations

$$\begin{aligned}
\eta_0^2 &= n_0 f + (0,0)\eta_0 + (0,1)\eta_1 + (0,2)\eta_2 + \ldots + (0,e-1)\eta_{e-1}, \\
\eta_0\eta_1 &= n_1 f + (1,0)\eta_0 + (1,1)\eta_1 + (1,2)\eta_2 + \ldots + (1,e-1)\eta_{e-1}, \\
\eta_0\eta_2 &= n_2 f + (2,0)\eta_0 + (2,1)\eta_1 + (2,2)\eta_2 + \ldots + (2,e-1)\eta_{e-1}, \\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
\eta_0\eta_{e-1} &= n_{e-1} f + (e-1,0)\eta_0 + (e-1,1)\eta_1 + (e-1,2)\eta_2 + \ldots + (e-1,e-1)\eta_{e-1},
\end{aligned}$$

and eliminates η_1, η_2, ... η_{e-1} from them. The symbol (k, h) represents the number of solutions of the congruence $\gamma^{ey+h} \equiv 1 + \gamma^{ex+k}$, mod λ, x and y denoting any two terms of a complete system of residues for the modulus f; n_k is zero for all values of k, excepting that $n_0 = 1$, if f be even, and $n_{\frac{1}{2}e} = 1$, if f be uneven[*]. The systems of equations corresponding to the particular cases $e=3$, $e=4$, have been given by Gauss, who has succeeded in expressing the values of the coefficients (k, h) in each of those cases by means of numbers depending on the representation of λ by certain simple quadratic forms; and has employed these expressions to demonstrate the criterion already mentioned in this Report for the biquadratic character of the number 2[†]. A third method has been given by M. Libri[‡]: he establishes the formula

$$\lambda N_k = \lambda^k + \eta_0(1 + e\eta_0)^k + \eta_1(1 + e\eta_1)^k + \ldots \eta_{e-1}(1 + e\eta_{e-1})^k,$$

in which N_k represents the number of solutions of the congruence

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[*] Liouville's Journal, vol. xvi. p. 404.

[†] Disq. Arith. art. 358, and Theor. Res. Biq. arts. 14–22.

[‡] See the memoir "Sur la Théorie des Nombres," in his 'Mémoires de Mathématique et de Physique,' pp. 121, 122. The notation of the memoir has been altered in the text. See also M. Lebesgue, in Liouville's Journal, vol. ii. p. 287, and vol. iii. p. 113.

$$1+x_1^e+x_2^e+\dots+x_k^e\equiv 0, \text{ mod } \lambda\,*.$$

If S_1, S_2, $S_3 \dots$ denote the sums of the powers of the roots of the equation $F(y)=0$, this formula may be written thus,—

$$\lambda N_k=\lambda^k+S_1+keS_2+\frac{k\,.\,k-1}{1\,.\,2}e^2S_3+\dots e^kS_{k+1},$$

or, solving for S_1, S_2, ...,

$$e^kS_{k+1}=\lambda\left[N_k-kN_{k-1}+\frac{k(k-1)}{1\,.\,2}N_{k-2}-\dots-(-1)^kN_1\right]-(\lambda-1)^k.$$

From this equation, when the values of N_1, N_2, &c., have been determined, S_1, S_2, ... may be calculated, and thence by known methods the values of the coefficients of the equation $F(y)=0$. Lastly, M. Lebesgue has shown that, if we denote by σ_k the number of ways in which numbers divisible by λ can be formed by adding together k terms of the series $\gamma^0, \gamma^1, \dots \gamma^{\lambda-2}$, subject to the condition that no two powers of γ be added the indices of which are congruous for the modulus e, the function $(\lambda-1)F(y)$ assumes the form

$$\lambda[y^e-\sigma_1y^{e-1}+\sigma_2y^{e-2}-\dots+(-1)^e\sigma_e]-(y-f)^e\,\dagger.$$

But the practical application of any of these methods is very laborious when λ is a large number, chiefly on account of the determinations which they all require of the numbers of solutions of which certain congruences are susceptible. For $e=2$ the equation is $y^2+y+\dfrac{1-(-1)^\mu\lambda}{4}=0$, or, putting $r=2y+1$, $r^2-(-1)^\mu\lambda=0$. The cubic and biquadratic equations corresponding to the cases $e=3$ and $e=4$ are also known from Gauss's investigations. The results assume the simplest forms if we put $r=ey+1$. We then have

(1) $e=3$, $4\lambda=M^2+27N^2$, $M\equiv 1$, mod 3; $r^3-3\lambda r-\lambda M=0$.

(2) $e=4$; $\lambda=A^2+B^2$; $A\equiv 1$, mod 4; $\epsilon=(-1)^f$.

$$[r^2+(1-2\epsilon)\lambda]^2-4\lambda(r-A)^2=0\,\ddagger.$$

Though these determinations are not required in M. Kummer's theory, we have nevertheless given them here, in order to facilitate arithmetical verifications of his results. The forms of the period-equations for the case $r=8$ and $e=12$ can (it may be added) be elicited from the results given by Jacobi in his note on the division of the circle (Crelle, vol. xxx. pp. 167, 168.).

44. *The Period-Equations considered as Congruences.*—An arithmetical property of the equation $F(y)=0$, which renders it of fundamental importance in the theory of complex numbers, is expressed in the following theorem.

"If q be a prime number satisfying the congruence $q^f\equiv 1$, mod λ, the congruence $F(y)=0$, mod q, is completely resoluble, *i. e.* it is possible to establish an indeterminate congruence of the form

$$F(y)\equiv(y-u_0)(y-u_1)\dots(y-u_{e-1}), \text{ mod } q,$$

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* In this congruence $x_1, x_2, \dots x_k$ are k terms (the same or different) of a *complete* system of residues for the modulus λ; and in counting the number of solutions, two solutions are to be considered as different in which the same places are not occupied by the same numbers. A simpler formula for S_{k+1} may be obtained by considering $x_1, x_2, \dots x_k$ to represent terms of a system of residues prime to λ, and denoting by $e^k\gamma_k$ the number of solutions of M. Libri's congruence on this hypothesis. We thus find $S_{k+1}=\lambda\gamma_k-f^k$ (Liouville, vol. iii. p. 116).

† Liouville, vol. iii. p. 119.

‡ M. Lebesgue, Comptes Rendus, vol. li. p. 9. Gauss has not exhibited this last equation in its explicit form. See Theor. Res. Biq. *l. c.*

$u_0, u_1, \ldots u_{e-1}$ denoting integral numbers, congruous or incongruous, mod q*."

A particular case of this theorem, relating to the equation $\frac{x^\lambda - 1}{x-1} = 0$ (which may of course be regarded as the equation of the $\lambda - 1$ periods, consisting each of a single root), is due to Euler, and is included in his theory of the Residues of Powers; for it follows from that theory (see art. 12 of this Report), that the binomial congruence $x^\lambda - 1 \equiv 0$ (and therefore also the congruence $\frac{x^\lambda - 1}{x-1} \equiv 0$, mod q) is completely resoluble for every prime of the form $m\lambda + 1$.

A remarkable relation subsists between the periods $\eta_0, \eta_1 \ldots \eta_{e-1}$ of the *equation* $F(y) = 0$, and the roots $u_0, u_1, u_2 \ldots u_{e-1}$ of the *congruence* $F(y) \equiv 0$, mod q. This relation is expressed in the following theorem:—

"Every equation which subsists between any two functions of the periods, will subsist as a congruence for the modulus q when we substitute for the periods the roots of the congruence $F(y) \equiv 0$ taken in a certain order."

It is immaterial which root of the congruence we take to correspond to any given root of the equation. But when this correspondence has once been established in a single case, we must attend to the sequence which exists among the roots of the congruence corresponding to the sequence of the periods. When $u_0, u_1, \ldots u_{e-1}$ are all incongruous, their order of sequence is determined by the congruences

$$u_1 \equiv \phi(u_0), \quad u_2 \equiv \phi(u_1), \ \ldots \ldots \ u_0 \equiv \phi(u_{e-1}), \text{ mod } q,$$

which correspond to the equations

$$\eta_1 = \phi(\eta_0), \quad \eta_2 = \phi(\eta_1), \ \ldots \ldots \ \eta_0 = \phi(\eta_{e-1}),$$

and which are always significant, although the coefficients of ϕ are fractional, because it may be proved that their denominators are prime to the modulus q. When $u_0, u_1, \ldots u_{e-1}$ are not all incongruous [an exceptional case which implies that q divides the *discriminant* of $F(y)$], a precisely similar relation subsists, though it cannot be fixed in the same manner, and though the number of incongruous solutions of the congruence is not equal to the number of the periods. (See a paper by M. Kummer in Crelle's Journal,

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* This theorem was first given by Schoenemann (Crelle, vol. xix. p. 306); his demonstration, however, supposes that $q \geqq e$,—a limitation to which the theorem itself is not subject. The following proof is, with a slight modification, that given by M. Kummer (Crelle, vol. xxx. p. 107, or Liouville, vol. xvi. p. 408). From the indeterminate congruence of Lagrange (see art. 10 of this Report)

$$x(x-1)(x-2)\ldots\ldots(x-q+1) \equiv x^q - x, \text{ mod } q,$$

it follows that

$$(y-\eta_k)(y-\eta_k-1)(y-\eta_k-2)\ldots(y-\eta_k-q+1) \equiv (y-\eta_k)^q - (y-\eta_k)$$

$$\equiv y^q - \eta_k{}^q - (y-\eta_k) \equiv y^q - y, \text{ mod } q,$$

observing that $\eta_k{}^q \equiv \eta_{k+\text{Ind}\, q}$, and that, if Ind q be divisible by e (or, which is the same thing, if q satisfy the congruence $q^f \equiv 1$, mod λ), $\eta_{k+\text{Ind}\, q} = \eta_k$. Multiplying together the e congruences obtained by giving to k the e values of which it is susceptible in the formula

$$(y-\eta_k)(y-\eta_k-1)(y-\eta_k-2)\ldots(y-\eta_k-q+1) \equiv y^q - y, \text{ mod } q,$$

we find

$$F(y)\,F(y-1)\,F(y-2)\ \ldots\ F(y-q+1) \equiv (y^q - y)^e, \text{ mod } q;$$

whence, by a principle to which we shall have occasion to refer subsequently (see Art. 69), it appears that $F(y)$ is congruous for the modulus q to a product of the form

$$(y-u_0)(y-u_1)\ldots(y-u_{e-1}).$$

vol. liii. p. 142, in which he has established this fundamental proposition on a satisfactory basis.)

45. *Conditions for the Divisibility of the Norm of a Complex Number by a Real Prime**.—Instead of the complex number

$$f(\alpha)=a_0+a_1\,\alpha+a_2\,\alpha^2+\;\ldots\ldots\;+a_{\lambda-2}\,\alpha^{\lambda-2},$$

let us now, for a moment, consider the complex number

$$\psi(\eta_0)=c_0\,\eta_0+c_1\,\eta_1+c_2\,\eta_2+\;\ldots\ldots\;+c_{e-1}\,\eta_{e-1},$$

which, with its conjugates

$$\psi(\eta_1)=c_0\,\eta_1+c_1\,\eta_2+c_2\,\eta_3+\;\ldots\ldots\;+c_{e-1}\,\eta_0,$$

$$\psi(\eta_2)=c_0\,\eta_2+c_1\,\eta_3+c_2\,\eta_4+\;\ldots\ldots\;+c_{e-1}\,\eta_1,$$

$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$

$$\psi(\eta_{e-1})=c_0\,\eta_{e-1}+c_1\,\eta_0+c_2\,\eta_1\ldots\ldots+c_{e-1}\,\eta_{e-2},$$

is a function of the periods only, and is therefore a specialized form of the general complex number $f(\alpha)$; and let q still denote a real prime, satisfying the congruence $q^f\equiv1$, mod λ. By means of the relation subsisting between the equation-roots $\eta_0,\ \eta_1,\ \ldots\ \eta_{e-1}$, and the congruence-roots $u_0,\ u_1,\ \ldots\ u_{e-1}$, M. Kummer has demonstrated the two following theorems:—

(i.) "The necessary and sufficient condition that $\psi(\eta)$ should be divisible by q (*i. e.* that the coefficients $c_0,\ c_1,\ \ldots\ c_{e-1}$ should be all separately divisible by q) is that the e congruences

$$\psi(u_0)\;\;=c_0\,u_0\;\;\;+c_1\,u_1+c_2\,u_2+\;\ldots\ldots\;+c_{e-1}\,u_{e-1}\equiv0,\ \text{mod}\ q,$$

$$\psi(u_1)\;\;=c_0\,u_1\;\;\;+c_1\,u_2+c_2\,u_3+\;\ldots\ldots\;+c_{e-1}\,u_0\;\;\;\equiv0,\ \text{mod}\ q,$$

$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$

$$\psi(u_{e-1})=c_0\,u_{e-1}+c_1\,u_0+c_2\,u_1+\;\ldots\ldots\;+c_{e-1}\,u_{e-2}\equiv0,\ \text{mod}\ q,$$

should be simultaneously satisfied."

(ii.) "The necessary and sufficient condition that the norm of $\psi(\eta)$, taken with respect to the periods, *i. e.* the number $\psi(\eta_0)\,\psi(\eta_1)\ldots\ldots\psi(\eta_{e-1})$, should be divisible by q, is that *one* of the e congruences

$$\psi(u_0)\equiv0,\ \psi(u_1)\equiv0,\ \ldots\ldots\ \psi(u_{e-1})\equiv0,\ \text{mod}\ q,$$

should be satisfied."

These results may be extended to *any* complex number $f(\alpha)$, by first reducing it to the form

$$f(\alpha)=\psi_0(\eta_0)+\alpha\,\psi_1(\eta_0)+\alpha^2\,\psi_2(\eta_0)+\;\ldots\;+\alpha^{f-1}\,\psi_{f-1}(\eta_0).$$

This is always possible; for, since the f roots which compose any one period, *e. g.* η_0, are the roots of an equation $\chi(\alpha)=0$ of order f, the coefficients of which are complex integers involving the periods only†, we may simply divide $f(\alpha)$ by $\chi(\alpha)$, and the remainder will give us the expression of $f(\alpha)$ in the required form. Further, let q now denote a prime *appertaining to the exponent* f (not merely satisfying the congruence $q^f\equiv1$, mod λ, but also satisfying no congruence of lower index and of the same form). The two preceding theorems are then replaced by the two following, which are analogous to them, and include them.

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* The outline of the theory of complex numbers contained in this and the subsequent articles is chiefly derived from M. Kummer's mémoire in Liouville, vol. xvi. p. 411.

† Disq. Arith. art. 348.

(i.) "The necessary and sufficient condition that $f(\alpha)$ should be divisible by q, is that the congruences

$$\psi_0(u_k)\equiv 0,\ \psi_1(u_k)\equiv 0,\ \ldots\ \psi_{f-1}(u_k)\equiv 0,\ \text{mod } q,$$

should be simultaneously satisfied for every value of k."

(ii.) "And the condition that the norm of $f(\alpha)$ should be divisible by q, is that the same congruences should be satisfied for some one value of k."

When the congruences $\psi_0(u_k)\equiv 0$, $\psi_1(u_k)\equiv 0$, ... $\psi_{f-1}(u_k)\equiv 0$, mod q, are simultaneously satisfied, $f(\alpha)$ is said to be *congruous to zero (mod q), for the substitution* $\eta_0=u_k$. These f congruences may be replaced by a single congruence in either of two different ways. Thus, if we denote by $F(\eta_0)$ the complex number involving the periods only which we obtain by multiplying together the f complex numbers

$$f(\alpha), f(\alpha^{\gamma^e}), f(\alpha^{\gamma^{2e}}), \ldots .\ f(\alpha^{\gamma^{(f-1)e}}),$$

it may be proved that the single congruence $F(u_k)\equiv 0$, mod q, is precisely equivalent to the f congruences

$$\psi_0(u_k)\equiv 0,\ \psi_1(u_k)\equiv 0,\ \ldots .\ \psi_{f-1}(u_k)\equiv 0.$$

Or, again, if we denote by $\Psi(\eta_0)$ a complex number congruous to zero for every one of the substitutions $\eta_0=u_1$, $\eta_0=u_2$, ... $\eta_0=u_{e-1}$, but not congruous to zero for the substitution $\eta_0=u_0$ (such complex numbers, involving the periods only, can in every case be assigned)*, it is readily seen that the same f congruences are comprehended in the single formula

$$\Psi(\eta_{e-k})f(\alpha)\equiv 0,\ \text{mod } q.$$

The utility of this latter mode of expressing the f congruences will appear in the sequel: the formula $F(u_k)\equiv 0$, mod q, is of importance, because it supplies an immediate demonstration of the important proposition, that "if a product of two factors be congruous to zero for the substitution $\eta_0=u_k$, one or other of the factors must be congruous to zero for that substitution."

46. *Definition of Ideal Prime Factors.*—To develope the consequences of the preceding theorems, let us consider a prime number q appertaining to the exponent f; and let us first suppose that it is capable of being expressed as the norm (taken with respect to the periods) of a complex number $\psi(\eta_0)$, which contains the periods of f terms only; so that

$$q=\psi(\eta_0)\,\psi(\eta_1)\ldots .\ \psi(\eta_{e-1}).$$

If the substitution of u_0 in ψ render $\psi(u_0)\equiv 0$, mod q, we may distinguish the e factors of q by means of the substitutions which respectively render them congruous to zero; so that, for example, $\psi(\eta_{e-k})$ is the factor *appertaining to the substitution* $\eta_0=u_k$.

We thus obtain the theorem that if $f(\alpha)$ be congruous to zero, mod q, for any substitution $\eta_0=u_0$, $f(\alpha)$ is divisible by the factor of q appertaining to that substitution. For if $\psi(\eta_0)$ be that factor of q,

$$\frac{f(\alpha)}{\psi(\eta_0)}=\frac{f(\alpha)\psi(\eta_1)\psi(\eta_2)\ldots\psi(\eta_{e-1})}{q};$$

but $f(\alpha)\psi(\eta_1)\psi(\eta_2)\ldots\psi(\eta_{e-1})$ is congruous to zero, mod q, for every one of the substitutions $\eta_0=u_0$, $\eta_0=u_1$, ... $\eta_0=u_{e-1}$; it is consequently divisible by q; *i.e.* $f(\alpha)$ is divisible by $\psi(\eta_0)$. A useful particular case of this theorem is that $u_k-\eta_k\equiv 0$, mod $\psi(\eta_0)$, if $\psi(u_0)\equiv 0$, mod q.

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* Crelle, vol. liii. p. 145. The number $\Psi(\eta)$ of this memoir possesses the property in question.

Again, it may be shown that these complex factors of q are *primes* in the most proper sense of the word: *i.e.*, first, that they are incapable of resolution into any two complex factors, unless one of those factors be a complex unit; and secondly, that if any one of them divide the product of two factors, it necessarily divides one or other of the two factors separately. That $\psi(\eta_0)$ possesses the first property is evident, because its norm is a real prime, and that it possesses the second is a consequence of the last theorem of Art. 45. For if $\psi(\eta_0)$ divide $f_1(\alpha)\times f_2(\alpha)$, either $f_1(\alpha)$ or $f_2(\alpha)$, by virtue of that theorem, is congruous to zero (mod q) for the substitution $\eta_0=u_0$; that is to say, either $f_1(\alpha)$ or $f_2(\alpha)$ is divisible by $\psi(\eta_0)$.

Now, if every prime q which appertains to the exponent f were actually capable of resolution into e complex factors composed of the e periods of f roots, these factors would represent to us all the true primes to be considered in the theory of the residues of λth powers. And for values of λ inferior to 11, perhaps to 23, this is, in fact, the case. But for higher values of λ, the real primes appertaining to the exponent f divide themselves into two different groups, according as they are or are not susceptible of resolution into e conjugate factors. Let, then, q represent any prime appertaining to the exponent f, whether susceptible or not of this resolution, and let $f(\alpha)$ still denote a complex number which is rendered congruous to zero by the substitution $\eta_0=u_0$; $f(\alpha)$ is said by M. Kummer to contain *the ideal factor of q appertaining to the substitution $\eta_0=u_0$*. This definition is admissible, because it is verified, as we have just seen, when q is actually resoluble into e conjugate factors; and its introduction is justified, as M. Kummer observes, by its utility. To obtain a definition of the multiplicity of an ideal factor, we may employ a complex number $\Psi(\eta)$ possessing the property indicated in the last article. If of the two congruences

$$[\Psi(\eta_0)]^n \ f(\alpha)\equiv 0, \text{ mod } q^n,$$

$$[\Psi(\eta_0)]^{n+1} f(\alpha)\equiv 0, \text{ mod } q^{n+1},$$

the former be satisfied, and the latter not, $f(\alpha)$ is said to contain n times precisely the ideal factor of q which appertains to the substitution $\eta_0=u_0$.

47. *Elementary Theorems relating to Ideal Factors.*—The following propositions are partly restatements (in conformity with the definitions now introduced) of results to which we have already referred, and partly simple corollaries from them. They will serve to show that the elementary properties of ordinary integers may now be transferred to complex numbers.

(1.) A complex number is divisible by q when it contains all the ideal factors of q. If it contain all of those factors n times, but not all of them $n+1$ times, it is divisible by q^n, but not by q^{n+1}.

(2.) The norm of a complex number is divisible by q when the complex number contains one of the ideal factors of q. If (counting multiple factors) it contain, in all, k of the ideal factors of q, the norm is divisible by q^{kf}, but by no higher power of q (f denoting the exponent to which q appertains).

(3.) A product of two or more factors contains the same ideal divisors as its factors taken together.

(4.) The necessary and sufficient condition that one complex number should be divisible by another is, that the dividend should contain all the ideal factors of the divisor at least as often as the divisor.

(5.) Two complex numbers which contain the same ideal factors are identical, or else differ only by a unit factor.

(6.) Every complex number contains a finite number of ideal prime factors. These ideal prime factors (as well as the multiplicity of each of them) are perfectly determinate.

The prime number λ is the only real prime excluded from the preceding considerations. Since $\lambda=(1-\alpha)(1-\alpha^2)\ldots.(1-\alpha^{\lambda-1})$, it appears that the norm of $1-\alpha$ is a real prime, and therefore $1-\alpha$ cannot be resolved into the product of two factors, except one of them be a unit. Again, because the necessary and sufficient condition for the divisibility of a complex number by $1-\alpha$ is that the sum of the coefficients of the complex number should be congruous to zero for the modulus λ, and because the sum of the coefficients of a product of complex numbers is congruous, for the modulus λ, to the product of the sums of the coefficients of the factors, it appears that if the norm of a complex number is divisible by λ, the complex number is itself divisible by $1-\alpha$; and also that if the product of two complex numbers be divisible by $1-\alpha$, one or other of the factors separately must be divisible by $1-\alpha$. Hence $1-\alpha$ is a true complex prime, and is the only prime factor of λ; in fact, $\lambda=(1-\alpha)(1-\alpha^2)\ldots(1-\alpha^{\lambda-1})=e(\alpha)(1-\alpha)^{\lambda-1}$, if $e(\alpha)$ denote the complex unit

$$\frac{1-\alpha^2}{1-\alpha}\cdot\frac{1-\alpha^3}{1-\alpha}\cdots\cdot\frac{1-\alpha^{\lambda-1}}{1-\alpha}.$$

The theorems which have preceded enable us to give a definition of the norm of an ideal complex number. If the ideal number contain the factor $1-\alpha$ m times, and if it besides contain $k, k', k'', \ldots.$ prime factors of the primes $q, q', q'', \ldots.$ appertaining to the exponents $f, f', f'', \ldots.$ respectively, we are to understand by its norm, the positive integral number

$$\lambda^m q^{kf} q'^{k'f'} q''^{k''f''} \ldots.;$$

a definition which, by virtue of the second proposition of this article, is exact in the case of an actually existing number.

It will be observed that the number of actual or ideal prime factors (compound of λth roots of unity) into which a given real prime can be decomposed, depends exclusively on the exponent to which the prime appertains for the modulus λ. If the exponent is f, the number of ideal factors is $\frac{\lambda-1}{f}=e$. Thus, if q be a primitive root of λ, q continues a prime in the complex theory; if it be a primitive root of the congruence $x^{\frac{\lambda-1}{2}}\equiv 1$, mod λ, it is only resoluble into two conjugate prime factors. This dependence of the number of ideal prime factors of a given prime upon the exponent to which it appertains is a remarkable instance of an intimate and simple connexion between two properties of the same prime number, which appear at first sight to have no immediate connexion with one another.

It may be convenient to remark that the word Ideal is sometimes used so as to include, and sometimes so as to exclude, actually existent complex numbers; but it is not apprehended that any confusion can arise from this ambiguity, which it is not worth while to remove at the expense of introducing a new technical term.

48. *Classification of Ideal Numbers.*—An ideal number (using the term in its restricted sense) is incapable of being exhibited in an isolated form as a complex integer; as far as has yet appeared, it has no quantitative existence; and the assertion that a given complex number contains an ideal factor, is only a convenient mode of expressing a certain set of congruential conditions which are satisfied by the coefficients of the complex number. Nevertheless we may, without fear of error, represent ideal numbers by the same symbols, $f(\alpha)$, $F(\alpha)$, $\phi(\alpha)\ldots$, which we have employed to denote actually existing complex numbers, if we are only careful to remember that these symbols, when the numbers which they represent are ideal, admit of

combination by multiplication or division, but not by addition or subtraction. Thus $f(\alpha) \times f_1(\alpha)$, $f(\alpha) \div f_1(\alpha)$, $[f(\alpha)]^m$, are significant symbols, and their interpretation is contained in what has preceded; but we have no general interpretation of a combination such as $f(\alpha)+f_1(\alpha)$, or $f(\alpha)-f_1(\alpha)$*. This symbolic representation of ideal numbers is very convenient, and tends to abbreviate many demonstrations.

Every ideal number is a divisor of an actual number, and, indeed, of an infinite number of actual numbers. Also, if the ideal number $\phi(\alpha)$ be a divisor of the actual number $F(\alpha)$, the quotient $\phi_1(\alpha)=F(\alpha) \div \phi(\alpha)$ is always ideal; for if $\phi_1(\alpha)$ were an actual number, $\phi(\alpha)$, which is the quotient of $F(\alpha)$ divided by $\phi_1(\alpha)$, ought also to be an actual number. It appears, therefore, that there exists an infinite number of different ideal multipliers, which all render actual the same ideal number. It has, however, been shown by M. Kummer that a finite number of ideal multipliers are sufficient to render actual all ideal numbers whatever; so that it is possible (and that in an infinite number of different ways) to assign a system of ideal multipliers, such that every ideal number is rendered actual by one of them, and one only. Ideal numbers are thus distributed into a certain finite number of classes,—a class comprehending those numbers which are rendered actual by the same multiplier; and this distribution into classes is independent of the particular system of multipliers by which it is effected, inasmuch as it is found that if two ideal numbers be rendered actual by the same multiplier, every other multiplier which renders one of them actual will also render the other actual. Ideal numbers which belong to the same class are said to be *equivalent*; so that two ideal numbers, which are each of them equivalent to a third, are equivalent to one another. We may regard actual numbers (which need no ideal multiplier) as forming the first or *principal* class in the distribution, and, consequently, as all equivalent to one another. If $f(\alpha)$ be equivalent to $f_1(\alpha)$, and $\phi(\alpha)$ to $\phi_1(\alpha)$, $f(\alpha) \times \phi(\alpha)$ is equivalent to $f_1(\alpha) \times \phi_1(\alpha)$,—a result which is expressed by saying that "equivalent ideal numbers multiplied by equivalent numbers, give equivalent products;" and the class of the product is said to be the class *compounded* of the classes of the factors.

49. *Representation of Ideal Numbers as the roots of Actual Numbers.*—An important conclusion is deducible from the theorem that the number of classes of ideal numbers is finite. Let $f(\alpha)$ be any ideal number; and let us consider the series of ideal numbers $f(\alpha)$, $f(\alpha)^2$, $f(\alpha)^3$,... These numbers cannot all belong to different classes; we can therefore find two different powers of $f(\alpha)$, for example $[f(\alpha)]^m$ and $[f(\alpha)]^{m+n}$, which are equivalent to one another. But the equivalence of these numbers implies that $[f(\alpha)]^n$ is equivalent to the actual number $+1$; *i. e.* that $[f(\alpha)]^n$ is itself an actual number. We may therefore enunciate the theorem, "Every ideal number, raised to a certain power, becomes an actual number."

The index of this power is the same for all ideal numbers of the same class, but may be different for different classes. By reasoning precisely similar to that employed by Euler in his 2nd proof of Fermat's Theorem†, it may be proved that the index of the first term in the series $f(\alpha)$, $[f(\alpha)]^2$, $[f(\alpha)]^3$..., which is an actual number, is either equal to the whole number of classes, or to a submultiple of that number. This least index is said to be *the exponent to which the class of ideal numbers containing $f(\alpha)$ appertains.*

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* These symbols are, however, interpretable when $f(\alpha)$ and $f_1(\alpha)$ belong to the same *class*. Thus, if $\phi(\alpha) \times f(\alpha)$ and $\phi(\alpha) \times f_1(\alpha)$ be both actual, $f(\alpha)+f_1(\alpha)$ is the ideal quotient obtained by dividing $\phi(\alpha) \times f(\alpha) + \phi(\alpha) \times f_1(\alpha)$ by $\phi(\alpha)$.

† See art. 10 of this Report.

It would seem that for certain values of the prime λ, there exist classes of ideal numbers appertaining to the exponent H, if H denote the number of classes of ideal numbers*. Such classes (when they exist) possess a property similar to that of the primitive roots of prime numbers; *i.e.*, by compounding such a class continually with itself we obtain all possible classes, just as by continually multiplying a primitive root by itself we obtain all residues prime to the prime of which it is a primitive root. It has, however, been ascertained by M. Kummer that these *primitive* classes do not in all cases, or even in general, exist.

The theorem of this article enables us to express ideal numbers as roots of actually existing complex numbers. Thus, if q be a prime appertaining to the exponent f for the modulus λ, and resoluble into the product of e conjugate ideal factors $\phi(\eta_0), \phi(\eta_1), \phi(\eta_2), \ldots \phi(\eta_{e-1})$, these ideal numbers, which will not in general belong to the same class, will nevertheless appertain to the same exponent h; so that $[\phi(\eta_0)]^h$, $[\phi(\eta_1)]^h, \ldots$ will all be actual numbers. The power q^h is therefore resoluble into the product of e actually existing complex factors. If we effect this resolution, and represent the factors of q^h by $\Phi(\eta_0), \Phi(\eta_1) \ldots.$, the ideal numbers $\phi(\eta_0), \phi(\eta_1), \ldots.$ may be represented by the formulæ

$$\phi(\eta_0)=[\Phi(\eta_0)]^{\frac{1}{h}}, \phi(\eta_1)=[\Phi(\eta_1)]^{\frac{1}{h}}, \ldots..$$

50. *The Number of Classes of Ideal Numbers.*—The number of classes of ideal numbers was first determined by Dirichlet. He effected this determination by methods which he had previously introduced into the higher arithmetic, and which had already led him to a demonstration of the celebrated theorem, that every arithmetical progression, the terms of which are prime to their common difference, contains an infinite number of prime numbers, and to the determination of the number of non-equivalent classes of quadratic forms of a given determinant†. Dirichlet's investigation of the problem which we are here considering has never been published; but that since given by M. Kummer is probably in all essential respects the same, as it reposes on an extension of the principles developed in Dirichlet's earlier memoirs. Our limits compel us to omit the details of M. Kummer's analysis; the final result, however, is, that if H denote the number of non-equivalent classes of ideal numbers, $H=\frac{P}{(2\lambda)^{\mu-1}}\times\frac{D}{\Delta}$. In this formula P is a quantity defined by the equations

$$P=\phi(\beta)\,\phi(\beta^3)\,\phi(\beta^5)\ldots\phi(\beta^{\lambda-2}),$$
$$\phi(\beta)=1+\gamma_1\beta+\gamma_2\beta^2+\gamma_3\beta^3+\ldots+\gamma_{\lambda-2}\beta^{\lambda-2},$$

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* See on this subject M. Kummer's note "on the Irregularity of Determinants" in the Monatsberichte of the Berlin Academy for 1853, p. 194. M. Kummer's investigation, however, is restricted to classes containing ideal numbers $f(\alpha)$ such that $f(\alpha)\times f(\alpha^{-1})$ is an actual number.

† See his memoirs on Arithmetical Progressions, in the Transactions of the Berlin Academy for the years 1837 (p. 45) and 1841 (p. 141), or in Liouville, vol. iv. p. 393, ix. p. 255. The first of these papers relates to progressions of real integers, the second to progressions of complex numbers of the form $a+bi$. In the memoir "Recherches sur diverses applications de l'analyse infinitésimale à la Théorie des Nombres" (Crelle, vol. xix. p. 24, xxi. pp. 1, & 134), Dirichlet has applied his method to quadratic forms having real and integral coefficients; and in a subsequent memoir (Crelle, vol. xxiv. p. 291), he has extended this application to quadratic forms, of which the coefficients are complex numbers containing i. See also Crelle, vol. xviii. p. 259, xxi. p. 98 (or the Monatsberichte for 1840, p. 49), xxii. p. 375 (Monatsberichte for 1841, p. 190). We shall have occasion, in a later part of this Report, to give an abstract of the contents of this invaluable series of memoirs.

β representing a primitive root of the equation $\beta^{\lambda-1}=1$, γ a primitive root of the congruence $\gamma^{\lambda-1}\equiv 1$, mod λ, and $\gamma_1, \gamma_2, \gamma_3, \ldots$ the least positive residues of $\gamma, \gamma^2, \gamma^3, \ldots$ for the modulus λ; Δ is the logarithmic determinant (see art. 42 of this Report) of any system of $\mu-1$ fundamental units, and D the logarithmic determinant of a particular system of independent but not fundamental units, $e(\alpha), e(\alpha^{\gamma}), e(\alpha^{\gamma^2}) \ldots . e(\alpha^{\gamma^{\mu-2}})$, defined by the equation

$$e(\alpha)=\sqrt{\frac{(1-\alpha^{\gamma})(1-\alpha^{-\gamma})}{(1-\alpha)(1-\alpha^{-1})}}=\pm\frac{\alpha^{\mu(\gamma-1)}(1-\alpha^{\gamma})}{1-\alpha}=\pm\frac{\sin\frac{k\gamma\varpi}{\lambda}}{\sin\frac{\varpi}{\lambda}}, \text{ if } \alpha=\epsilon^{\frac{2ik\varpi}{\lambda}};$$

so that

$$D=\begin{vmatrix} L.e(\alpha), & L.e(\alpha^{\gamma}), & L.e(\alpha^{\gamma^2}), & \ldots . L.e(\alpha^{\gamma^{\mu-2}}) \\ L.e(\alpha^{\gamma}), & L.e(\alpha^{\gamma^2}), & L.e(\alpha^{\gamma^3}), & \ldots . L.e(\alpha^{\gamma^{\mu-1}} \\ L.e(\alpha^{\gamma^2}), & L.e(\alpha^{\gamma^3}), & L.e(\alpha^{\gamma^4}), & \ldots . L.e(\alpha^{\gamma^{\mu}}) \\ \ldots & & & \\ L.e(\alpha^{\gamma^{\mu-2}}), & L.e(\alpha^{\mu-1}), & L.e(\alpha^{\gamma^{\mu}}), & \ldots . L.e(\alpha^{\gamma^{2\mu-4}}). \end{vmatrix}$$

Each of the two factors $\frac{P}{(2\lambda)^{\mu-1}}$ and $\frac{D}{\Delta}$, of which the value of H is composed, is separately an integral number. That $\frac{D}{\Delta}$ is integral is a consequence of the relation which exists between the logarithmic determinant of a system of fundamental units, and that of any system of independent units; that P is divisible by $(2\lambda)^{\mu-1}$ may be rendered evident from the nature of the expression P itself*. The factor $\frac{D}{\Delta}$, taken by itself, represents the number of classes that contain ideal numbers composed with the periods of two terms $\alpha+\alpha^{-1}, \alpha^2+\alpha^{-2}, \ldots .$ only; or, which is the same thing, it represents the number of classes each of which contains the reciprocal $f(\alpha^{-1})$ of every ideal number $f(\alpha)$ comprehended in it; $\frac{P}{(2\lambda)^{\mu-1}}$, on the other hand, is the number of classes of those ideal numbers which become actual by multiplication with their own reciprocals†. The actual calculation of the factor $\frac{D}{\Delta}$ is extremely laborious, as it requires the preliminary investigation of a system of fundamental units. For the cases $\lambda=5$, $\lambda=7$, the *trigonometrical* units $e(\alpha)$, $e(\alpha^{\gamma}), e(\alpha^{\gamma^2}) \ldots$ are themselves a fundamental system, so that in these two cases $D=\Delta$, and $\frac{D}{\Delta}=+1$. The computation of the first factor $\frac{P}{(2\lambda)^{\mu-1}}$ presents somewhat less difficulty; and M. Kummer (though not without great labour) has assigned its value for all primes inferior to 100. For the primes 3, 5, 7, 11, 13, 17, 19, that value is unity; for 23 it is 3, and then increases with extraordinary rapidity; so that for 97 it already amounts to $411322823001=3457\times 118982593$. The asymptotic law of this increase is expressed by the formula

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* See the investigation in the next article.

† See the note already cited, "on the Irregularity of Determinants," in the Monatsberichte for 1853, p. 195.

$$\text{Lim}\left[\frac{\text{P}}{(2\lambda)^{\mu-1}}\div\frac{\lambda^{1+\frac{1}{2}\mu}}{2^{\mu-1}\varpi^{\mu}}\right]=1,$$

when λ increases * without limit. It will be seen that the number of classes of ideal numbers for $\lambda=3$, $\lambda=5$, $\lambda=7$, is unity; *i.e.*, for those values of λ every complex prime is actual. In the absence of any determination of a system of fundamental units for $\lambda=11$, $\lambda=13$, $\lambda=17$, and $\lambda=19$, it is not possible to say whether this is or is not the case for these values also. But from and after the limit $\lambda=23$, the value of the factor $\frac{\text{P}}{(2\lambda)^{\mu-1}}$ indicates that a complex number is not necessarily a complex prime because it is irresoluble into factors.

51. *Criterion of the Divisibility of* H *by* λ.—The number of classes of ideal numbers, which we have symbolized by H, is not in general divisible by λ; but in certain cases it may happen that it is so. The quotient $\frac{\text{D}}{\Delta}$ is never divisible by λ, except when the other factor $\frac{\text{P}}{(2\lambda)^{\mu-1}}$ is also divisible by λ. And it has been found by M. Kummer that the necessary and sufficient condition for the divisibility of $\frac{\text{P}}{(2\lambda)^{\mu-1}}$ by λ is that the numerator of one of the first $\mu-1$ fractions of Bernoulli should be divisible by λ. The investigation of this singular criterion depends on a transformation of the function $\phi(\beta)$ which enters into the expression of P. If we represent the product $(\gamma\beta-1)\,\phi(\beta)=(\gamma\gamma_{\lambda-2}-1)+(\gamma-\gamma_1)\beta+(\gamma\gamma_1-\gamma_2)\beta^2+\ldots.+(\gamma\gamma_{\lambda-3}-\gamma_{\lambda-2})\beta^{\lambda-2}$, in which every coefficient is divisible by λ, by

$$\lambda[b_0+b_1\beta+b_2\beta^2+\ldots b_{\lambda-2}\beta^{\lambda-2}],\text{ or }\lambda\psi(\beta)$$

(b_m denoting the quotient $\frac{\gamma\gamma_{m-1}-\gamma_m}{\lambda}$, or I $\frac{\gamma\gamma_{m-1}}{\lambda}$, if I represent the greatest integer contained in the fraction before which it is placed), we obtain by multiplication the equality

$$(\gamma^\mu+1)\text{P}=\lambda^\mu\psi(\beta)\psi(\beta^3)\ldots.\psi(\beta^{\lambda-2});$$

or, since $\gamma^\mu+1$ is divisible by λ, and may be supposed not divisible by λ^2†,

$$\frac{\text{C}\,.\,\text{P}}{(2\lambda)^{\mu-1}}=\psi(\beta)\psi(\beta^3)\ldots.\psi(\beta^{\lambda-2}),$$

C denoting a coefficient prime to λ. The congruence $\frac{\text{P}}{(2\lambda)^{\mu-1}}\equiv0$, mod λ, is therefore equivalent to the congruence

$$\psi(\beta)\,\psi(\beta^3)\ldots.\psi(\beta^{\lambda-2})\equiv0,\text{ mod }\lambda,$$

which may, in its turn, be replaced by the following,

$$\psi(\gamma)\,\psi(\gamma^3)\ldots\psi(\gamma^{\lambda-2})\equiv0,\text{ mod }\lambda.$$

For, if there be an equation which, considered as a congruence for a given modulus λ, is completely resoluble for that modulus, any symmetrical function of the roots of the congruence is congruous, for the modulus λ, to the corresponding function of the roots of the equation. The function $\psi(\beta)\,\psi(\beta^3)$

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* Liouville, vol. xvi. p. 473. The formula is given without demonstration.

† For $\gamma^\mu+1$ and $(\gamma+\lambda)^\mu+1$ are both of them divisible by λ; but only one of them can be divisible by λ^2, since their difference is not divisible by λ^2. We can therefore, without changing $\gamma_0\,\gamma_1\ldots\gamma_{\lambda-2}$, determine γ in accordance with the supposition in the text.

$\dots\psi(\beta^{\lambda-2})$, which is a symmetric function of $\beta, \beta^3, \dots \beta^{\lambda-2}$, the roots of the equation $x^\mu+1=0$, is therefore congruous to $\psi(\gamma)\,\psi(\gamma^3)\dots\psi(\gamma^{\lambda-2})$, which is the same function of $\gamma, \gamma^3, \gamma^5, \dots \gamma^{\lambda-2}$, the roots of the congruence $x^\mu+1\equiv 0$, mod λ. Hence the necessary and sufficient condition for the divisibility of $\frac{\mathrm{P}}{(2\lambda)^{\mu-1}}$ by λ is that one of the μ congruences included in the formula

$$\psi(\gamma^{2n-1})\equiv 0, \text{ mod } \lambda, \ n=1, 2, 3 \dots \mu, \ . \ . \ . \ . \ . \ . \quad \text{(a)}$$

should be satisfied. Now $\gamma^{-(2n-1)}\psi(\gamma^{2n-1})\equiv b_0\gamma_{\lambda-2}^{2n-1}+b_1\gamma_0^{2n-1}+b_2\gamma_1^{2n-1}+\dots+b_{\lambda-2}\gamma_{\lambda-3}^{2n-1}$; or, observing that $\gamma_0, \gamma_1, \gamma_2 \dots \gamma_{\lambda-2}$ are the numbers $1, 2, 3, \dots \lambda-1$, taken in a certain order, and introducing the values of $b_0, b_1, b_2, \dots$

$$\gamma^{-(2n-1)}\psi(\gamma^{2n-1})\equiv \sum_{x=1}^{x=\lambda-1} x^{2n-1}\,\mathrm{I}\frac{\gamma x}{\lambda}, \text{ mod } \lambda.$$

This last expression may be further transformed as follows. If $f(x)$ denote any function of x, and $\mathrm{F}(x)=\sum_{x=1}^{x=x} f(x)$, we have the identical equation

$$\sum_{x=1}^{x=\lambda-1} \mathrm{I}\frac{\gamma x}{\lambda}.f(x)+\sum_{x=1}^{x=\gamma-1} \mathrm{F}\left(\mathrm{I}\frac{\lambda x}{\gamma}\right)=(\gamma-1)\,\mathrm{F}(\lambda-1),$$

γ and λ being any two numbers prime to one another. To verify this equation, we may construct a system of unit points in a plane; then the right-hand member is the sum of the values of $f(x)$ for all unit points in the *interior* of the parallelogram $(0, 0)$, $(\lambda, 0)$, (λ, γ), $(0, \gamma)$; while the two terms of the left-hand member represent similar sums for the two triangles into which the parallelogram is divided by its diagonal $\gamma x-\lambda y=0$. Writing then in this identity x^{2n-1} for $f(x)$, and employing the symbol $\mathrm{F}_{2n-1}(x)$ to represent the sum $\sum_{x=1}^{x=x} x^{2n-1}$, or rather the function

$$\frac{x^{2n}}{2n}+\tfrac{1}{2}x^{2n-1}+\mathrm{B}_1\frac{\Pi.2n-1}{\Pi.2n-2.\Pi.2}.x^{2n-2}-\mathrm{B}_2\frac{\Pi.2n-1}{\Pi.2n-4.\Pi.4}x^{2n-4}+\dots$$
$$+(-1)^{n-1}\mathrm{B}_{n-1}\frac{\Pi.2n-1}{\Pi.2.\Pi.2n-2}x^2,$$

in which $\mathrm{B}_1\ \mathrm{B}_2 \dots \mathrm{B}_n$ are the fractions of Bernoulli, and which, when x is an integral number, coincides with that sum, we find

$$\sum_{x=1}^{x=\lambda-1} x^{2n-1}\,\mathrm{I}\frac{\gamma x}{\lambda}+\sum_{x=1}^{x=\gamma-1} \mathrm{F}_{2n-1}\left[\mathrm{I}\frac{\lambda x}{\gamma}\right]=(\gamma-1)\,\mathrm{F}_{2n-1}(\lambda-1).$$

But $\mathrm{F}_{2n-1}(\lambda-1)=\mathrm{F}_{n2-1}(\lambda)-\lambda^{2n-1}$ is evidently divisible by λ; so that

$$\sum_{x=1}^{x=\lambda-1} x^{2n-1}\,\mathrm{I}\frac{\gamma x}{\lambda}+\sum_{x=1}^{x=\gamma-1} \mathrm{F}_{2n-1}\left[\mathrm{I}\frac{\lambda x}{\gamma}\right]\equiv 0, \text{ mod } \lambda.$$

The congruences (a) may therefore be replaced by the congruences $\sum_{x=1}^{x=\gamma-1} \mathrm{F}_{2n-1}\left[\mathrm{I}\frac{\lambda x}{\gamma}\right]\equiv 0$, mod λ, which may be written in the simpler form

$$\sum_{x=1}^{x=\gamma-1} \mathrm{F}_{2n-1}\left(-\frac{x}{\gamma}\right) \equiv 0, \bmod \lambda,$$

if we observe that (λ being prime to γ) the numbers $\mathrm{I}\frac{\lambda}{\gamma}, \mathrm{I}\frac{2\lambda}{\gamma}, \ldots \mathrm{I}\frac{(\gamma-1)\lambda}{\gamma}$ are congruous (mod λ) to the fractions $-\frac{1}{\gamma}, -\frac{2}{\gamma}, \ldots -\frac{\gamma-1}{\gamma}$, taken in a certain order. But, by a curious property of the function F_{2n-1}, demonstrated for the first time by M. Kummer,

$$\sum_{x=1}^{x=\gamma-1} \mathrm{F}_{2n-1}\left(-\frac{x}{\gamma}\right) = \frac{(-1)^n \mathrm{B}_n (\gamma_{2n}-1).}{2n\gamma^{2n-1}}$$

The condition for the divisibility of H by λ is therefore that one of the μ congruences included in the formula $\mathrm{B}_n(\gamma^{2n}-1) \equiv 0$, mod λ, should be satisfied. The last of these congruences, or $\mathrm{B}_\mu(\gamma^{2\mu}-1) \equiv 0$, is never satisfied; for it is easily proved that the denominator of B_μ contains λ as a factor, while $\gamma^{2\mu}-1=(\gamma^\mu+1)(\gamma^\mu-1)$, though divisible by λ, is not divisible by λ^2. And since, if $n<\mu$, $\gamma^{2n}-1$ is prime to λ, that factor may be omitted in the remaining $\mu-1$ congruences; so that the condition at which we have arrived coincides with that enunciated at the commencement of this article.

We have exhibited M. Kummer's analysis of this problem with more fulness of detail than might seem warranted by the nature of this Report, not only on account of its elegance, but also because it exemplifies transformations and processes which are of frequent occurrence in arithmetical investigation[*].

52. "*Exceptional*" *Primes.*—A prime number λ, which, like 37, 59, and 67 in the first hundred, divides the numerator of one of the first $\frac{\lambda-3}{2}$ fractions of Bernoulli, and which consequently divides the number of classes of ideal numbers composed with λth roots of unity, is termed by M. Kummer an *exceptional* prime. Such primes have to be excluded from the enunciation of several important propositions; and their theory presents difficulties which have not yet been overcome. Thus the following propositions are true for all primes other than the exceptional primes, but are not true for the exceptional primes.

(1.) The exponent to which any class of ideal numbers appertains (see art. 49) is prime to λ.

(2.) The index of the lowest power of any unit which can be expressed as a product of *integral* powers of the trigonometric units is prime to λ. For that index is a divisor of $\frac{\mathrm{D}}{\Delta}$ (see art. 42).

(3.) Every complex unit which is congruous to a real integer for the modulus λ is a perfect λth power. (Whether λ be an exceptional prime or not, the λth power of any complex number is congruous, for the modulus λ, to a real integer, viz. to the sum of the coefficients of the complex number.)

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[*] In Liouville, vol. i. (New Series) p. 396, M. Kronecker has given a very simple demonstration of the congruence

$$2n\lambda\psi(\gamma^{2n-1}) \equiv (\gamma^{2n}-1)\,[1^{2n}+2^{2n}+\ldots+(\lambda-1)^{2n}], \bmod \lambda^2,$$

which, combined with another easily demonstrated formula, viz.,

$$1^{2n}+2^{2n}+\ldots(\lambda-1)^{2n} \equiv (-1)^{n-1}\mathrm{B}_n\lambda, \bmod \lambda^2\ [n<\mu],$$

leads immediately to the theorem of M. Kummer.

(4.) If $f(\alpha)$ denote any (actual) complex number prime to λ (*i. e.* not divisible by $1-\alpha$), a complex unit $e(\alpha)$ can always be assigned, such that the product $F(\alpha)=e(\alpha)f(\alpha)$ shall satisfy the two congruences

$$F(\alpha)\,F(\alpha^{-1})\equiv[F(1)]^2,\ \text{mod}\ \lambda,$$
$$F(\alpha)\equiv F(1),\ \text{mod}\ (1-\alpha)^2.$$

A complex number satisfying these two congruential conditions is called a *primary* complex number; the product of two primary numbers is therefore itself primary. This definition, in the particular case $\lambda=3$, includes the primary numbers of art. 37, taken either positively or negatively.

53. *Fermat's Theorem for Complex Primes.*—Let $\phi(\alpha)$ be an actual or ideal complex prime, and let $N=N.\phi(\alpha)$ represent its norm. A system of N actual numbers can always be assigned such that every complex number shall be congruous to one and only to one of them for the modulus $\phi(\alpha)$. These N numbers may be said therefore to form a complete system of residues for the modulus $\phi(\alpha)$; and by omitting the term divisible by $\phi(\alpha)$, we obtain a system of $N-1$ residues prime to $\phi(\alpha)$.

Let q be a prime appertaining to the exponent f, so that $N=q^f$, and let $\phi(\alpha)$ or $\phi_1(\eta_0)$ be the prime factor of q which appertains to the substitution $\eta_0=u_0$; the formula

$$a_0+a_1\alpha+a_2\alpha^2+\ldots+a_{f-1}\alpha^{f-1}, \qquad \text{(A)}$$

will represent a complete system of residues for the modulus $\phi_1(\eta_0)$, if we assign to the coefficients $a_0, a_1, a_2 \ldots.$ the values $0, 1, 2, \ldots q-1$, in succession. For if $f(\alpha)=\psi_0(\eta_0)+\alpha\,\psi_1(\eta_0)+\ldots+\ldots\alpha^{f-1}\psi_{f-1}(\eta_0)$ be any complex number, $f(\alpha)$ is congruous for the modulus $\phi_1(\eta_0)$ to $\psi_o(u_0)+\alpha\psi_1(u_0)+\ldots+\alpha^{f-1}\psi_{f-1}(u_0)$, because $u_0-\eta_0\equiv0$, mod $\phi_1(\eta_0)$; that is, $f(\alpha)$ is congruous to one of the complex numbers included in (A); nor can any two numbers $a_0+a_1\alpha+a_2\alpha^2+\ldots+a_{f-1}\alpha^{f-1}$ and $b_0+b_1\alpha+b_2\alpha^2+\ldots+b_{f-1}\alpha^{f-1}$ included in that formula be congruous to one another; for the congruence $(a_0-b_0)+\alpha(a_1-b_1)+\alpha^2(a_2-b_2)+\ldots+\alpha^{f-1}(a_{f-1}-b_{f-1})\equiv0$, mod $\phi_1(\eta_0)$, involves, by M. Kummer's theory (see art. 45), the coexistence of the f congruences $a_0-b_0\equiv0$, mod q; $a_1-b_1\equiv0$, mod q; $\ldots a_{f-1}-b_{f-1}\equiv0$, mod q; *i. e.* the identity of the complex numbers $a_0+\alpha a_1+\alpha^2a_2+\ldots\alpha^{f-1}a_{f-1}$, and $b_0+\alpha b_1+\alpha^2b_2+\ldots+\alpha^{f-1}b_{f-1}$. It is worth while to notice that, if q be a prime appertaining to the exponent 1, for the modulus λ, *i. e.* if q be of the linear form $m\lambda+1$, the real numbers $0, 1, 2, 3\ldots q-1$ will represent the terms of a complete system of residues for the modulus $\phi(\alpha)$; but if $\phi(\alpha)$ be a factor of a prime appertaining to any higher exponent than unity, a complete system will contain complex as well as real integral residues.

By applying the principle (see art. 10) that a system of residues prime to the modulus, multiplied by a residue prime to the modulus, produces a system of residues prime to the modulus, we obtain the theorem, which here replaces Fermat's Theorem, that if $\psi(\alpha)$ be any actual number prime to $\phi(\alpha)$, $[\psi(\alpha)]^{N-1}\equiv1$, mod $\phi(\alpha)$. If we combine with this theorem the principle of Lagrange (cited in art. 11) which is valid for complex no less than for real prime modules, we may extend, *mutatis mutandis*, to the general complex theory the elementary propositions relating to the Residues of Powers, Primitive Roots, and Indices, which, as we have seen, exist in the case of complex primes formed with cubic or biquadratic roots of unity. In fact, these propositions are of a character of even greater generality, and may be extended, not only to complex numbers formed with roots of unity whose index is a composite number, but also to all complex numbers formed with the roots of equations having integral coefficients, as soon as the prime factors of those complex numbers are properly defined.

54. *M. Kummer's Law of Reciprocity.*—We can now enunciate M. Kummer's law of reciprocity. It appears, from the last article, or it may be proved immediately by dividing the $N-1$ residues of $\phi(\alpha)$ into λ groups of $\frac{N-1}{\lambda}$ terms, after the following scheme,

$$\begin{array}{ll}
(0) & r_1,\ r_2,\ \ldots\ldots\ r_{\frac{N-1}{\lambda}} \\
(1) & ar_1,\ ar_2,\ \ldots\ldots\ ar_{\frac{N-1}{\lambda}} \\
(2) & a^2r_1,\ a^2r_2,\ \ldots\ldots\ a^2r_{\frac{N-1}{\lambda}} \\
(\lambda-1) & a^{\lambda-1}r_1,\ a^{\lambda-1},\ \ldots\ldots\ a^{\lambda-1}r_{\frac{N-1}{\lambda}}
\end{array}$$

and proceeding as in art. 33 of this Report, that if $\psi(\alpha)$ be any actual complex number prime to $\phi(\alpha)$, $\psi(\alpha)^{\frac{N-1}{\lambda}}$ is congruous for the modulus $\phi(\alpha)$ to a certain power α^k of α. This power of α may be denoted by the symbol $\left[\frac{\psi(\alpha)}{\phi(\alpha)}\right]_\lambda$; so that we have the congruence $[\psi(\alpha)]^{\frac{N-1}{\lambda}} \equiv \left[\frac{\psi(\alpha)}{\phi(\alpha)}\right]_\lambda \equiv \alpha^k$, mod $\phi(\alpha)$. The symbol $\left[\frac{\psi(\alpha)}{\phi(\alpha)}\right]_\lambda$ which we may term the λtic character of $\psi(\alpha)$ with regard to $\phi(\alpha)$, is evidently of the same nature as the corresponding symbols with which we have already met in the quadratic, cubic, and biquadratic theories, and admits of an extension of meaning similar to that of which they are susceptible. Availing himself of this symbol, M. Kummer has expressed his law of reciprocity by the formula $\left[\frac{\psi(\alpha)}{\phi(\alpha)}\right]_\lambda = \left[\frac{\phi(\alpha)}{\psi(\alpha)}\right]_\lambda$, $\phi(\alpha)$ and $\psi(\alpha)$ denoting real or ideal primes. But, to interpret this equation rightly, it is important to attend to the following observations.

(1.) When $\psi(\alpha)$ and $\phi(\alpha)$ are both actual numbers, the formula supposes that they are both *primary* prime numbers. The prime $1-\alpha$ is therefore excluded.

(2.) The definition that we have given of the symbol $\left[\frac{\phi(\alpha)}{\psi(\alpha)}\right]_\lambda$ becomes unmeaning when $\phi(\alpha)$ is ideal, because no signification can be assigned to an ideal number which presents itself, not as a modulus or divisor, but as a residue. Let, therefore, h denote the index of the lowest power of $\phi(\alpha)$ which is an actual number; *i. e.*, let h be the exponent to which the class of $\phi(\alpha)$ appertains; and let $[\phi(\alpha)]^h$ represent the actually existing *primary* complex number which contains the factor $\phi(\alpha)$ h times, but contains no other prime factor; then the symbol $\left[\frac{\phi(\alpha)}{\psi(\alpha)}\right]_\lambda$ has by the preceding definition a perfectly definite meaning. Let then $\left[\frac{\phi(\alpha)^h}{\psi(\alpha)}\right]_\lambda = \alpha^{k'}$; we may define the value of the symbol $\left[\frac{\phi(\alpha)}{\psi(\alpha)}\right]_\lambda$ by means of the equation $\left[\frac{\phi(\alpha)}{\psi(\alpha)}\right]^h = \left[\frac{\phi(\alpha)^h}{\psi(\alpha)}\right] = \alpha^{k'}$, which, *if h be prime to* λ, always gives a determinate value

α^k for $\left[\frac{\phi(\alpha)}{\psi(\alpha)}\right]$, k being defined by the congruence $hk \equiv k'$, mod λ. For the symbol $\left[\frac{\phi(\alpha)}{\psi(\alpha)}\right]$ so defined, the law of reciprocity still subsists, subject however to the condition that $[\phi(\alpha)]^h$ is primary.

It will be seen, therefore, that the exceptional primes of art. 52 are excluded from M. Kummer's law of reciprocity, for a twofold reason :—first, because if λ be one of those numbers, the definition of a primary number is not in general applicable; and secondly, because, on the same supposition, the symbol $\left[\frac{\phi(\alpha)}{\psi(\alpha)}\right]_\lambda$ may become unmeaning.

55. *The Theorems complementary to M. Kummer's Law of Reciprocity.*—The prime $1-\alpha$, and its conjugate primes, as well as the complex units, are excluded from the law of reciprocity; but complementary theorems by which the λtic characters of these numbers may be determined have been given by M. Kummer. For a simple unit α^k, we have the formula $\left(\frac{\alpha^k}{\phi(\alpha)}\right)_\lambda = \alpha^{k\frac{N-1}{\lambda}}$. With regard to λ, which is the norm of $1-\alpha$, it may be observed that if $\phi(\alpha)$ be a prime factor of a real prime q appertaining, for the modulus λ, to any exponent f different from unity, *i. e.* if q be not of the linear form $m\lambda+1$, the character of every real integer, and therefore of λ, with respect to $\phi(\alpha)$ is $+1$, because, if $f>1$, $\frac{q^f-1}{\lambda}$ is divisible by $q-1$. But whatever be the linear form of q, the *characteristic* of λ or $\chi(\lambda)$ (for so we shall for brevity term the index of α in the equation $\left[\frac{\lambda}{\phi(\alpha)}\right]_\lambda = \alpha^k$), is determined by the congruence

$$\chi(\lambda) \equiv \frac{1}{\lambda} D_\lambda, \text{ mod } \lambda,$$

D_λ being the value (for $v=0$) of the differential coefficient $\frac{d^\lambda \log \phi(e^v)}{dv^\lambda}$ if $\phi(\alpha)$ be an actually existent number, or of $\frac{1}{h}\frac{d^\lambda \log \phi(e^v)^h}{dv^\lambda}$ if it be ideal. To obtain the characteristics of the units, M. Kummer considers the system of independent units

$$E_1(\alpha), E_2(\alpha), \ldots\ldots E_{\mu-1}(\alpha),$$

defined by the formula

$$E_k(\alpha) = e(\alpha)\, e(\alpha^\gamma)^{\gamma^{-2k}}\, e(\alpha^{\gamma^2})^{\gamma^{-4k}} \ldots\ldots e(\alpha^{\gamma^{\mu-1}})^{\gamma^{-2(\mu-1)k}}$$

in which $e(\alpha)$ represents the trigonometrical unit of art. 50, and γ is the same primitive root of λ which occurs in the expression of $e(\alpha)$. We have then, for $\chi[E^k(\alpha^n)]$ and $\chi(1-\alpha^k)$, the formulæ

$$\chi[E_k(\alpha^n)] \equiv (-1)^k(\gamma^{2k}-1)\frac{B_k n^{2k}}{4k} D_{\lambda-2k}, \text{ mod } \lambda,$$

and

$$\chi(1-\alpha^k) \equiv -\frac{D_\lambda}{\lambda} + \tfrac{1}{2}\frac{N-1}{\lambda} + B_1 D_{\lambda-2}\frac{k^2}{2}$$

$$-B_2 D_{\lambda-4}\frac{k^4}{4} + \ldots\ldots + (-1)^\mu B_{\mu-1} D_3 \frac{k^{\lambda-3}}{\lambda-3},$$

N representing the norm of $\phi(\alpha)$, $B_1, B_2 \ldots B_{\mu-1}$ the fractions of Bernoulli, and D_m the value of the differential coefficient

$$\frac{d^m \log \phi(e^v)}{dv^m} \left(\text{or } \frac{d^m \log [\phi(e^v)]^h}{h\,dv^m}\right) \text{ for } v=0.$$

These formulæ do not in general hold for the *exceptional* prime numbers λ, which divide the numerator of one of the first $\mu-1$ fractions of Bernoulli. This is evident from the occurrence in them of the coefficients D_m, which if $\phi(\alpha)$ be ideal, and h be divisible by λ, may acquire denominators divisible by λ, thus rendering the congruences nugatory. It is sufficient to have determined the characteristics of the particular system of units $E_1(\alpha)$, $E_2(\alpha)$, $\ldots E_{\mu-1}(\alpha)$, because, as that system is independent, every other unit $\epsilon(\alpha)$ is included in the formula

$$\epsilon(\alpha)=E_1(\alpha)^{m_1} E_2(\alpha)^{m_2} \ldots\ldots E_{\mu-1}(\alpha)^{m_{\mu-1}};$$

so that $\chi[\epsilon(\alpha)]$ may be found from the congruence

$$\chi[\epsilon(\alpha)] \equiv \sum_{k=1}^{k=\mu-1} m_k\, \chi[E_k(a)], \bmod \lambda,$$

which cannot become unmeaning, except in the case of the exceptional primes, because if D' be the logarithmic determinant of the system of units $E_1(\alpha)$, $E_2(\alpha)$, $\ldots E_{\mu-1}(\alpha)$, D and Δ retaining the meanings assigned to them in art. 50, it may be shown that $\frac{D'}{D}$ is prime to λ, and therefore $\frac{D'}{\Delta}=\frac{D'}{D}\times\frac{D}{\Delta}$ is also prime to λ; *i. e.*, the denominators of the fractions $m_1, m_2, \ldots m_{\mu-1}$ are prime to λ (see art. 42). But M. Kummer has also given a formula which assigns directly the characteristic of any unit $\epsilon(\alpha)$ whatsoever. If Δ_k denote the value of the differential coefficient $\frac{d^k \log \epsilon(e^v)}{dv^k}$, for $v=0$, we have

$$\chi[\epsilon(\alpha)] \equiv \Delta_1 \frac{N-1}{\lambda} + \sum_{k=1}^{k=\mu-1} \Delta_{2k}\, D_{\lambda-2k}, \bmod \lambda^*.$$

56. We have already observed (see art. 39) that it is impossible to deduce a proof of the highest laws of reciprocity from the formulæ which present themselves in the theory of the division of the circle. It is true (as we shall presently see) that the formulæ IV. and V. of art. 30 determine the decomposition of the real prime p (supposed to be of the form $k\lambda+1$) into its $\lambda-1$ complex prime factors; but it will be perceived that these complex factors occur, not isolated, but combined in a particular manner. From equation IV. of the article cited we infer that $p=\psi(\alpha)\,\psi(\alpha^{-1})$; let then $\psi(\alpha)=f(\alpha_1) f(\alpha_2) \ldots f(\alpha_\mu)$; $\alpha_1, \alpha_2 \ldots \alpha_\mu$ being μ different roots (of which no two are reciprocals) of the equation $\frac{\alpha^\lambda-1}{\alpha-1}=1$; so that $f(\alpha_1), f(\alpha_2), \ldots f(\alpha_\mu)$ are one-half of the complex primes of which p is composed; if $e(\alpha)$ be any *real* unit, satisfying the equation $e(\alpha)=e(\alpha^{-1})$, it is plain that $e(\alpha_1)^2 e(\alpha_2)^2 \ldots e(\alpha_\mu)^2=1$, or $\psi(\alpha)=\pm e(\alpha_1) f(\alpha_1) \times e(\alpha_2) f(\alpha_2) \ldots \times e(\alpha_\mu) f(\alpha_\mu)$. The consideration, therefore, of the number $\psi(\alpha)$ cannot supply us with any determination of the λtic character of $f(\alpha_1)$ which will not equally apply to $f(\alpha_1) \times e(\alpha_1)$. But for all values of λ greater than 3, the number of real complex units is, as we have seen, infinite; and the character of any complex prime $f(\alpha)$ with respect to any other complex prime evidently changes

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* The formulæ of this article are taken from M. Kummer's second memoir on the complementary theorems (Crelle, vol. lvi. p. 270).

when $f(\alpha)$ is multiplied by a unit of which the λtic character is not unity. The inapplicability of the formulæ of art. 30 to any general demonstration of the law of reciprocity is thus apparent. The only equation of reciprocity that has been elicited from them is the following:—

$$\left(\frac{\phi(\alpha)}{q_1}\right)_\lambda\times\left(\frac{\phi(\alpha)}{q_2}\right)_\lambda\times\ldots\ldots\times\left(\frac{\phi(\alpha)}{q_e}\right)_\lambda=\left(\frac{q_1}{\phi(\alpha)}\right)_\lambda\times\left(\frac{q_2}{\phi(\alpha)}\right)_\lambda\times\ldots\ldots\times\left(\frac{q_e}{\phi(\alpha)}\right)_\lambda,$$

in which $\phi(\alpha)$ is a complex prime factor of a prime number p of the form $m\lambda+1$, and $q_1, q_2, \ldots . q_e$ are the e conjugate factors of a prime number q appertaining to the exponent f for the modulus λ. This equation, which, if we adopt the generalized meaning of the symbol of reciprocity, may be written more briefly thus, $\left(\frac{\phi(\alpha)}{q}\right)_\lambda=\left(\frac{q}{\phi(\alpha)}\right)_\lambda$, was first obtained by Eisenstein, who inferred it from M. Kummer's investigation of the ideal prime divisors of $\psi(\alpha)$ (see a note addressed by Eisenstein to Jacobi, and communicated by Jacobi to the Berlin Academy, in the Monatsberichte for 1850, May 30, p. 189). In a later memoir (Crelle's Journal, vol. xxxix. p. 351), Eisenstein proposes an ingenious method—reposing, however, on an undemonstrated principle—for the discovery of the higher laws of reciprocity; but it would seem that the application of this method failed to lead him to any definite result; and it is unquestionably to M. Kummer alone that we are indebted for the enunciation as well as for the demonstration of the theorem.

57. M. Kummer appears to have waited until he had developed the theory of complex numbers with a certain approximation to completeness, before proceeding to apply the principles he had discovered to the purpose which he had in view throughout, the investigation of the law of reciprocity. He succeeded in discovering the law which we have enunciated, in the year 1847, and, after verifying it by calculated tables of some extent, he communicated it to Dirichlet and Jacobi in January 1848, and subsequently, in 1850, to the Berlin Academy, in a note which also contained the demonstration of the complementary theorems relating to the units, and the prime divisors of λ. From the analogy of the cubic theorem, it was natural to conjecture that the law of reciprocity would assume the simple form $\left(\frac{p_1}{p_2}\right)_\lambda=\left(\frac{p_2}{p_1}\right)_\lambda$ for primes p_1 and p_2 reduced, by multiplication with proper complex units, to a form satisfying certain congruential conditions. But to determine properly these conditions, *i. e.* to assign the true definition of a primary complex prime, was no doubt the principal difficulty that M. Kummer had to overcome in the discovery of his theorem. If $\lambda=3$, the single congruence $f(\alpha)\equiv f(1)$, mod $(1-\alpha)^2$, sufficiently characterizes a primary number; and since, whatever prime be represented by λ, that congruence is satisfied by one, and one only, of the numbers included in the formula $\alpha^k f(\alpha)$, it was probable that it ought to form one of the congruential conditions included in the definition of a primary complex prime. In determining the second condition, M. Kummer appears to have been guided by a method which depends on the arithmetical properties of the logarithmic expansion of a complex number. If we develope $\log\frac{f(\alpha)}{f(1)}$ in ascending powers of $\frac{f(\alpha)-f(1)}{f(1)}$ and represent by $\mathrm{L}\frac{f(\alpha)}{f(1)}$ the finite number of terms which remain in this expansion after rejecting those which are congruous to zero for the modulus λ, we are led, after some transformations, to the congruence

$$-\mathrm{L}\cdot\frac{f(\alpha)}{f(\alpha)} \equiv \mathrm{D}_1\,\mathrm{X}_1(\alpha)+\mathrm{D}_2\,\mathrm{X}_2(\alpha)+\ldots+\mathrm{D}_{\lambda-2}\,\mathrm{X}_{\lambda-2}(\alpha), \text{ mod } \lambda,$$

where $\mathrm{X}_k(\alpha)$ represents the function $\sum\limits_{s=0}^{s=\lambda-2} \gamma^{-sk}\,\alpha^{\gamma^s}$, and D_k denotes, as in art. 55, the differential coefficient $\frac{d_0^k \log f(e^v)}{dv^k}$. In this congruence the first coefficient alone is altered when $f(\alpha)$ is multiplied by a simple unit; and only the even coefficients are altered when $f(\alpha)$ is multiplied by a real unit. Now D_1 is rendered congruous to zero by the condition $f(\alpha) \equiv f(1)$, mod $(1-\alpha)^2$; and M. Kummer has shown that, by multiplying $f(\alpha)$ by a properly chosen real unit, $\mathrm{D}_2, \mathrm{D}_4, \ldots \mathrm{D}_{\lambda-3}$ may be similarly made to disappear, so that we obtain

$$-\mathrm{L}\frac{f(\alpha)}{f(1)} \equiv \mathrm{D}_3\,\mathrm{X}_3(\alpha)+\mathrm{D}_5\,\mathrm{X}_5(\alpha)+\ldots+\mathrm{D}_{\lambda-2}\,\mathrm{X}_{\lambda-2}(\alpha), \text{ mod } \lambda,$$

a congruence which is proved to involve the second congruence of condition satisfied by a primary number, *i. e.* $f(\alpha)f(\alpha^{-1}) \equiv f(1)^2$, mod λ*.

58. The methods to which M. Kummer at first had recourse in order to obtain a demonstration of his theorem, consisted in extensions of the theory of the division of the circle. By such extensions he demonstrated the complementary theorems, and even a particular case of the law of reciprocity itself—that in which the two complex primes compared are conjugate. But, after repeated efforts, he found himself compelled to abandon these methods, and to seek elsewhere for more fertile principles. "I turned my attention," he says, "to Gauss's second demonstration of the law of quadratic reciprocity, which depends on the theory of quadratic forms. Though the method of this demonstration had never been extended to any other than quadratic residues, yet its principles appeared to me to be characterized by such generality as led me to hope that they might be successfully applied to residues of higher powers; and in this expectation I was not disappointed†."

M. Kummer's demonstration of the law of reciprocity was communicated to the Academy of Berlin in the year 1858, ten years after the date of his first discovery of it. An outline of the demonstration is contained in the Monatsberichte for that year; and it is exhibited with great clearness and fulness of detail in a memoir published in the Berlin Transactions for 1859, which contains what is for the present the latest result of science on a problem which, if we date from the first enunciation of the quadratic theorem by Euler, has been studied by so many eminent geometers for nearly a century. It would, however, be impossible, without exceeding the limits within which this Report is confined, to give an account of its contents, which should be intelligible to persons not already familiar with the subject to which it refers. Taken by itself the demonstration of the theorem is, indeed, sufficiently simple; but it is based on a long series of preliminary researches relating to the complex numbers that can be formed with the roots of the equation $w^\lambda = \mathrm{D}(\alpha)$, in which $\mathrm{D}(\alpha)$ itself denotes a complex number composed of λth roots of unity. To those researches, and to the demonstration of the law of reciprocity founded on them, we shall again very briefly refer, when we come to speak of the corresponding investigations in the theory of quadratic forms, an acquaintance with which is essential to a comprehension of the method adopted by M. Kummer in his memoir. We may add that M. Kummer has intimated that he has already obtained two other demonstrations of his law of reciprocity, which, though they also depend on the consideration of complex numbers containing w, yet do not require the same complicated preliminary considerations.

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* Crelle, vol. xliv. p. 130–140.

† See the Berlin Transactions for 1859, p. 29.

59. *Complex Numbers composed of Roots of Unity, of which the Index is not a Prime.*—In a special memoir (see the list in art. 41, note, No. 16), M. Kummer has considered the theory of complex numbers composed with a root of the equation $\omega^n=1$, in which n denotes a composite number. The *primitive* roots of this equation are the roots of an irreducible equation of the form

$$F(\omega)=\frac{(\omega^n-1)\,\Pi\left(\omega^{\frac{n}{p_1 p_2}}-1\right)\ldots\ldots}{\Pi\left(\omega^{\frac{n}{p}}-1\right)\Pi\left(\omega^{\frac{n}{p_1 p_2 p_3}}-1\right)\ldots\ldots}=0,$$

$p_1, p_2, p_3, \ldots\ldots$ denoting the different prime divisors of n*. If $\psi(n)$ be the number of numbers less than n and prime to it, $F(\omega)$ is of the order $\psi(n)$, and every complex number containing ω can be reduced (and that in one way only) to the form $f(\omega)=a_0+a_1\omega+a_2\omega^2+\ldots\ldots+a_{\psi(n)-1}\,\omega^{\psi(n)-1}$. The numbers conjugate to $f(\omega)$ are the $\psi(n)$ numbers obtained by writing in succession for ω the $\psi(n)$ primitive roots of $\omega^n=1$; and the norm of $f(\omega)$ is the real and positive integer produced by multiplying together the $\psi(n)$ conjugates. If q be a prime number not dividing n, the sum

$$\varpi_k=\omega^k+\omega^{kq}+\omega^{kq^2}+\ldots\ldots,$$

in which the series of terms is to be continued until it begins to repeat itself, is termed a period. The n periods $\varpi_1, \varpi_2, \ldots \varpi_n$ remain unchanged if for ω we write ω^q, ω^{q^2}, etc. Hence, if q appertain to the exponent t for the modulus n (*i. e.* if q satisfy the congruence $q^t\equiv 1$, mod n, but no congruence of a lower order and similar form), the number of different numbers conjugate to a given complex number containing the periods only is at most $\frac{\psi(n)}{t}$. For brevity, a complex number containing the periods only—for example, the number

$$c_0+c_1\varpi_1+c_2\varpi_2+\ldots\ldots+c_n\varpi_n,$$

may be symbolized by $f(\varpi_1)$, so that

$$f(\varpi_k)=c_0+c_1\varpi_k+c_2\varpi_{2k}+\ldots\ldots+c_n\varpi_{nk}.$$

If $1, r_1, r_2, \ldots$ are a set of $\frac{\psi(n)}{t}$ numbers prime to n and such that the quotient of no two of them (considered as a congruential fraction†) is congruous for the modulus n to any power of q, the numbers conjugate to $f(\varpi)$ may be represented by $f(\varpi_1)$, $f(\varpi_{r_1})$, $f(\varpi_{r_2})$ ..... The periods are the roots of certain irreducible equations, each of which is completely resoluble when considered as a congruence for the modulus q; and the roots $u_1, u_2, \ldots$ of the congruences are connected with the roots $\varpi_1, \varpi_2, \ldots$ of the equations, by a relation precisely similar to that enunciated in art. 44. This relation M. Kummer has established by introducing certain conjugate complex numbers* $\Psi(\varpi_1)$, $\Psi(\varpi_{r_1})$, $\Psi(\varpi_{r_2})$, ... involving the periods only, not themselves divisible by q, but each satisfying the n congruences included in the formula

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* The irreducibility of the equation $\frac{x^n-1}{x-1}=0$ when n is a prime was first established by Gauss (Disq. Arith. art. 341). For other and simpler demonstrations of the same theorem, see the memoirs of MM. Kronecker (Crelle, xxix. p. 280, and Liouville, 2nd series, vol. i. p. 399), Schoenemann (Crelle, vol. xxxi. p. 323, vol. xxxii. p. 100, & vol. xl. p. 188), Eisenstein (Crelle, vol. xxxix. p. 166), and Serret (Liouville, vol. xv. p. 296). The principles on which these demonstrations depend suffice to establish the irreducibility of the equation $\frac{x^{p^m}-1}{x^{p^{m-1}}-1}=0$, but they fail, as M. Kronecker has observed, to furnish the corresponding demonstration when n, as in the text, is a product of powers of different primes. This demonstration was first given by M. Kronecker (Liouville, vol. xix. p. 177), who has been followed by M. Dedekind (Crelle, vol. liv. p. 27), and by M. Arndt (*ib.* lvi. p. 178).

† For the definition of a congruential fraction see art. 14.

$$\Psi(\varpi_r)(\varpi_{kr}-u_k)\equiv 0, \text{ mod } q,$$
$$k=1, 2, 3, \ldots n.$$

From these congruences it is easy to infer that, if $f(\varpi_r, \varpi_{2r}, \ldots \varpi_{nr})=0$ be any identical relation subsisting for the periods, a similar relation $f(u_1, u_2, \ldots u_n)\equiv 0$, mod q, will subsist for the numbers $u_1, u_2, \ldots u_n$; for we find

$$\Psi(\varpi_r) f(\varpi_r, \varpi_{2r}, \ldots)\equiv \Psi(\varpi_r) f(u_1, u_2 \ldots), \text{ mod } q,$$

i. e. $f(u_1, u_2, \ldots)\equiv 0$, mod q. Another important property of the complex number $\Psi(\varpi_1)$ is that it is congruous to zero, mod q, for every one of the substitutions $\varpi_1=u_1$, $\varpi_1=u_{r_1}$, $\varpi_1=u_{r_2}$, ... except the first: thus the congruences $\Psi(u_{r_1})\equiv 0$, $\Psi(u_{r_2})\equiv 0$ are satisfied, ... but not $\Psi(u_1)\equiv 0$, mod q. If, then, $f(\omega)$ be any complex number satisfying the congruence $\Psi(\varpi_r)^m f(\omega)\equiv 0$, mod q^m, but not the congruence $\Psi(\varpi_r)^{m+1} f(\omega)\equiv 0$, mod q^{m+1}, $f(\omega)$ is said to contain m times precisely the ideal factor of q corresponding to

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* These complex numbers are defined as follows (see the memoir cited at the commencement of this article, sect. 3, and that in Crelle, vol. liii. p. 142):—Let ϖ_k be a period satisfying the irreducible equation $\phi(\varpi_k)=0$, and let $a_1, a_2, \ldots$ be the incongruous roots of $\phi(y)\equiv 0$, mod q, $b_1, b_2, \ldots$ the remaining terms of a complete system of residues, mod q, so that $\phi(b_1)$, $\phi(b_2)$, ... are prime to q. Since $\varpi_k^q\equiv\varpi_{kq}$, mod q, and $\varpi_{kq}=\varpi_k$, we have, by Lagrange's indeterminate congruence (see art. 10 of this Report)

$$(\varpi_k-a_1)(\varpi_k-a_2)\ldots\ldots(\varpi_k-b_1)(\varpi_k-b_2)\ldots\ldots\equiv 0, \text{ mod } q,$$

or, since ϖ_k-b_1 divides $\phi(b_1)$ etc.,

$$\phi(b_1)\,\phi(b_2)\ldots\ldots(\varpi_k-a_1)(\varpi_k-a_2)\ldots\equiv 0, \text{ mod } q;$$

i. e. $(\varpi_k-a_1)(\varpi_k-a_2)\ldots\ldots\equiv 0$, mod q. We may now consider the n series of factors

$$\varpi_k-a_1, \ \varpi_k-a_2, \ \varpi_k-a_3,$$

corresponding to the n values of k [the numbers $a_1, a_2, \ldots$ are of course the same for two periods which satisfy the same irreducible equation, but not in general the same for any two periods], and, retaining among these factors only those which are different, we may take for $\Psi(\varpi_1)$ the complex number formed by combining as many of them as possible, in such a manner as to give a product which is not divisible by q, but which is rendered divisible by q by the accession of any one factor not already contained in it. It is evident that $\Psi(\varpi_1)$ cannot contain all the factors ϖ_k-a_1, ϖ_k-a_2, ... ; let us then denote by ϖ_k-u_k a factor which is not contained in $\Psi(\varpi_1)$; we thus obtain the relation

$$\Psi(\varpi_1)(\varpi_k-u_k)\equiv 0, \text{ mod } q,$$

or, changing the primitive root ω into ω^r,

$$\Psi(\varpi_r)(\varpi_{rk}-u_k)\equiv 0, \text{ mod } q.$$

The conjugates of $\Psi(\varpi_1)$ are all complex numbers formed according to the same law as $\Psi(\varpi_1)$ itself; and, besides $\Psi(\varpi_1)$ and its conjugates, no other complex number can be formed according to that law. Also the number u_k which corresponds to a given period ϖ_k is absolutely determined as soon as we have selected the multiplier $\Psi(\varpi_1)$; for if two of the factors ϖ_k-a_1, ϖ_k-a_2, ... were absent from $\Psi(\varpi_1)$ we should have $\Psi(\varpi_1)(\varpi_k-a_1)\equiv 0$, $\Psi(\varpi_1)(\varpi_k-a_2)\equiv 0$, mod q; and thence $(a_1-a_2)\,\Psi(\varpi_1)\equiv 0$, mod q, contrary to the hypothesis that a_1 and a_2 are incongruous, and that $\Psi(\varpi_1)$ is not divisible by q. The correspondence of the numbers $u_1, u_2, \ldots\ldots u_n$, with the periods $\varpi_1, \varpi_2, \ldots \varpi_n$, can thus be fixed in as many ways as there are numbers conjugate to $\Psi(\varpi_1)$, *i. e.* in $\frac{\psi(n)}{t}$ different ways.

the substitution $\varpi_{kr}=u_k$. Since it can be shown that the numbers conjugate to $\Psi(\varpi_1)$ are all different from one another, it follows from the definition, that the quotient $\frac{\psi(n)}{t}$ represents the number of conjugate ideal prime factors contained in the real prime q, appertaining to the exponent t. If q be a divisor of n, the definition of its ideal factors requires a certain modification, which we cannot here particularize. (See sect. 6 of M. Kummer's Memoir.) The two definitions, corresponding to the cases of q prime to n, and q a divisor of n, enable us, when taken together, to transfer to the general case when n is composite, the elementary theorems already shown to exist when n is prime (see art. 47). We may add that it is easy to prove, in the general as in the special case (see art. 48), that the number of *classes* of ideal numbers is finite.

60. *Application to the Theory of the Division of the Circle.*—We cannot quit the subject of complex numbers without mentioning certain important investigations in which they have been successfully employed. The first relates to the problem of the division of the circle. In this problem the resolvent function of Lagrange $\sum\limits_{s=0}^{s=p-2} \theta^s x^{\gamma^s}$ (see art. 30) is, as is well known, of primary importance. Retaining, with a slight modification, the notation of art. 30, and still representing by λ a prime divisor of $p-1$, and by α a root of the equation $\frac{\alpha^\lambda-1}{\alpha-1}=0$, let us consider the function $F(\alpha, x)$, which is a particular case of the resolvent, and let us represent the quotient $\frac{F(\alpha, x)\, F(\alpha^k, x)}{F(\alpha^{k+1}, x)}$ by $\psi_k(\alpha)$. We thus find

$$[F(\alpha, x)]^s=\psi_1(\alpha)\,\psi_2(\alpha)\ldots\ldots\psi_{s-1}(\alpha)\,F(\alpha^s, x), \quad \ldots \quad (1)$$

and in particular, observing that $F(\alpha, x)\, F(\alpha^{\lambda-1}, x)=p$,

$$[F(\alpha, x)]^\lambda=p\psi_1(\alpha)\,\psi_2(\alpha)\ldots\ldots\psi_{\lambda-2}(\alpha), \quad \ldots\ldots\ldots \quad (2)$$

a result which is in accordance with the known theorem that $[F(\alpha, x)]^\lambda$ is independent of x and is an integral function of α only. The resolution of the auxiliary equation of order λ, the roots of which are the λ periods of $\frac{p-1}{\lambda}$ roots of the equation $\frac{x^p-1}{x-1}=0$, depends solely on the determination of the complex numbers $\psi_1(\alpha), \psi_2(\alpha), \ldots\ldots \psi_{\lambda-2}(\alpha)$. For when these complex numbers are known, we may equate $F(\alpha, x)$ to any λth root of the expression $p\psi_1(\alpha)\,\psi_2(\alpha)\ldots\psi_{\lambda-2}(\alpha)$; from the value of $F(\alpha, x)$, thus obtained, those of $F(\alpha^2, x), F(\alpha^3, x)\ldots\ldots$ may be inferred by means of equation (1); and, lastly, from the values of $F(1, x), F(\alpha, x), \ldots F(\alpha^{\lambda-1}, x)$, the values of the periods themselves are deducible by the solution of a system of linear equations. To determine the numbers $\psi_1(\alpha), \psi_2(\alpha), \ldots$ M. Kummer assigns the ideal prime factors of which they are composed, employing for this purpose the results cited in art. 30. The equation $\psi_k(\alpha)\,\psi_k(\alpha^{-1})=p$ shows that $\psi_k(\alpha)$ contains precisely $\frac{1}{2}(p-1)$ ideal prime divisors of p, and no other complex prime. To distinguish the prime factors of p contained in $\psi_k(\alpha)$ from those contained in $\psi_k(\alpha^{-1})$ M. Kummer avails himself of the congruence V. of art. 30, viz.,

$$\psi(\gamma)\equiv-\frac{\Pi(m+n)}{\Pi m.\Pi n}, \text{ mod } p.$$

Let $\lambda'=\frac{p-1}{\lambda}$, and $u\equiv\gamma^{\lambda'}$, mod p, so that $u, u^2, \ldots u^{\lambda-1}$ are the roots of

$\frac{x^\lambda-1}{x-1} \equiv 0$, mod p; also, to adapt the formulæ of art. 30 to our present purpose, let $\theta^{-\lambda'}=\alpha$, $m=\lambda'$, $n=k\lambda'$; it will result from these substitutions, that $\psi_k(u^{-h})\equiv 0$, mod p, if k and h satisfy the inequality $[h]+[kh]>\lambda$, where $[h]$ and $[kh]$ are positive numbers less than λ, and congruous, mod λ, to h and kh respectively. If we represent by $f(\alpha)$ the ideal prime factor of p which appertains to the substitution $\alpha=u$, this may be expressed by saying that $\psi_k(\alpha)$ contains the factor $f(\alpha^{-h})$, if $\left[\frac{1}{h}\right]+\left[\frac{k}{h}\right]>\lambda$, the symbols $\left[\frac{1}{h}\right]$ and $\left[\frac{k}{h}\right]$ denoting the least positive numbers satisfying the congruences $hx\equiv 1$, mod λ, and $hx\equiv k$, mod λ. Assigning, therefore, to the number h every positive value less than λ compatible with this condition, we may write

$$\psi_k(\alpha)=\pm\alpha^s\,\Pi f(\alpha^{-h}),$$

$\pm\alpha^s$ being a simple unit which may be determined by the congruence $\psi_k(\alpha)\equiv -1$, mod $(1-\alpha)^2$*: it is not necessary to add a real complex unit, for a reason which has already appeared (see art. 56, *supra*). From the expression for $\psi_k(\alpha)$ a still simpler formula for $F(\alpha,x)^\lambda$ may be obtained, viz.

$$[F(\alpha,x)]^\lambda=\pm\alpha^s\,\prod_{m=1}^{m=\lambda-1}[f(\alpha^{-m})]^{\left[\frac{1}{m}\right]}\dagger.$$

61. *Application to the Last Theorem of Fermat.*—The second investigation to which we shall advert relates to the celebrated proposition known as the "Last Theorem of Fermat," viz. that the equation $x^n+y^n=z^n$ is irresoluble, in integral numbers, for all values of n greater than 2‡. As Fermat himself

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* The numbers $\psi_k(\alpha)$ are *primary* according to M. Kummer's definition (art. 52); for $\psi_k(\alpha)=\frac{F(\alpha,x)\,F(\alpha^k,x)}{F(\alpha^{k+1},x)}=\Sigma\alpha^{y_1+ky_2}$, the summation extending to every pair of values of y_1 and y_2 that satisfy the congruence $\gamma^{y_1}+\gamma^{y_2}\equiv 1$, mod p, in which γ represents the same primitive root of p that occurs in the expression $F(\alpha,x)$. Hence $\psi_k(1)=p-2\equiv -1$, mod λ, and $\psi_k(\alpha)\,\psi_k(\alpha^{-1})=p\equiv 1\equiv[\psi_k(1)]^2$, mod λ. Also $\psi_k(\alpha)-\psi_k(1)$ is divisible by $(1-\alpha)^2$; for $\psi'_k(1)=\Sigma(y_1+ky_2)=\tfrac{1}{2}(1+k)\,(p-1)\,(p-2)$, observing that y_1 and y_2 each receive all the values $1, 2, \ldots p-2$ in succession. We have, therefore, the congruence $\psi'_k(1)\equiv 0$, mod λ, from which it follows (see a note on the next article) that $\psi_k(\alpha)\equiv\psi_k(1)$, mod $(1-\alpha)^2$, or $\psi_k(\alpha)\equiv -1$, mod $(1-\alpha)^2$, as in the text.

† Lionville, vol. xvi. p. 448. M. Kummer has also extended his solution of this problem to the case in which n is any divisor of $p-1$. See the memoir quoted in the last article, sect. 11.

‡ Fermat's enunciation of this celebrated theorem is contained in the first of the MS. notes placed by him on the margin of his copy of Bachet's edition of Diophantus. It would seem that this copy is now lost; but in the year 1670 an edition of Bachet's Diophantus was published at Toulouse, by Samuel de Fermat (the son of the great geometer), in which these notes are preserved (Diophanti Alexandrini Arithmeticorum libri sex, et de Numeris Multangulis liber unus, cum commentariis C. G. Bacheti V. C. et observationibus D. P. de Fermat senatoris Tolosani. Tolosæ 1670). The theorems contained in them are, with a few exceptions, enunciated without proof; and it may be inferred from the preface of S. Fermat, that he found no demonstration of them among his father's papers. Nevertheless, in the case of several of these propositions, we have the assertion of Fermat himself, that he was in possession of their demonstration; and although, when we consider the imperfect state of analysis in his time, it is surprising that he should have succeeded in creating methods which subsequent mathematicians have failed to rediscover, yet there is no ground for the suspicion that he was guilty of an untruth, or that he mistook an apparent for a real proof. In fact these suspicions are refuted, not only by the reputation for honour and veracity which he enjoyed among his contemporaries, and by the evidence of singular clearness of insight which his extant writings supply, but also by the facts of the case itself. It would be inex-

has left us a proof of the impossibility of this equation in the case of $n=4$, by a method which Euler has extended to the case of $n=3$, we may suppose, without loss of generality, that n is an uneven prime λ greater than 3, and we

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plicable, if his conclusions reposed on induction only, that he should never have adopted an erroneous generalization; and yet, with the exception of the "Last Theorem" (the demonstration of which, after two centuries, is still incomplete), every proposition of Fermat's has been verified by the labours of his successors. There is, indeed, one other exception to this statement; but it is an exception which proves the rule. In the letter to Sir Kenelm Digby which concludes the 'Commercium Epistolicum, etc.' edited by Wallis (Oxford, 1658), Fermat enuntiates the proposition that the numbers contained in the formula $2^{2^n}+1$ are all primes, acknowledging, however, that, though convinced of its truth, he had not succeeded in obtaining its demonstration. This letter, which is undated, was written in 1658; but it appears, from a letter of Fermat's to M. de * * *, dated October 18, 1640, that even at that earlier date he was acquainted with the proposition, and had convinced himself of its truth (D. Petri de Fermat Varia Opera Mathematica, Tolosæ, 1679, p. 162). It was, however, subsequently observed by Euler that $2^{2^5}+1=4294967297=641\times6700417$, i. e. that the undemonstrated proposition is untrue (Op. Arith. collecta, vol. i. p. 356). The error, if it is an error, is a fortunate one for Fermat; it exemplifies his candour and veracity, and it shows that he did not mistake inductive probability for rigorous demonstration:—"Mais je vous advoue tout net," are his words in the letter last referred to, "(car par advance je vous advertis que comme je ne suis pas capable de m'attribuer plus que je ne sçay, je dis avec même franchise ce que je ne sçay pas) que je n'ay peu encore démonstrer l'exclusion de tous diviseurs en cette belle proposition que je vous avois envoyée, et que vous m'avez confermée touchant les nombres 3, 5, 17, 257, 6553, &c. Car bien que je reduise l'exclusion à la pluspart des nombres, et que j'aye même des raisons probables pour le reste, je n'ay peu encore démonstrer nécessairement la vérité de cette proposition, de laquelle pourtant je ne doute non plus à cette heure que je faisois auparavant. Si vous en avez la preuve assurée, vous m'obligerez de me la communiquer: car après cela rien ne m'arrestera en ces matières."

The "Last Theorem" is enunciated by Fermat as follows:—

"Cubum autem in duos cubos, aut quadrato-quadratum in duos quadrato-quadratos, et generaliter nullam in infinitum ultrà quadratum potestatem in duos ejusdem nominis fas est dividere; cujus rei demonstrationem mirabilem sane detexi. Hanc marginis exiguitas non caperet." (Fermat's Diophantus, p. 51.)

Fermat has also asserted that neither the sum (*ibid.* p. 258) nor the difference (*ibid.* p. 338) of two biquadrates can be a square. Each of these propositions comprehends the theorem that the sum of two biquadrates cannot be a biquadrate; and of the second, we possess a very remarkable demonstration by Fermat himself (*ibid.* p. 338; and compare Euler, Elémens d'Algèbre, vol. ii. sect. 13; Legendre, Théorie des Nombres, vol. ii. p. 1). The essential part of this demonstration consists in showing that, from any supposed solution of the Diophantine equation $x^4-y^4=$ a square, another solution may be deduced in which the values of the indeterminates are not equal to zero, and yet are absolutely less than in the proposed solution, from which it immediately follows that the Diophantine equation is impossible. This method has been successfully employed by Euler (*loc. cit.*) to demonstrate several negative Diophantine propositions, and in particular the theorem that the sum of two cubes cannot be a cube. The only arithmetical principles (not included in the first elements of the science) which are employed by Euler and Fermat in their applications of this method, relate to certain simple properties of the quadratic forms x^2+y^2, x^2+2y^2, x^2+3y^2; and as these principles seem inadequate to overcome the difficulties presented by the equation $x^n+y^n+z^n=0$, when n is >4, it is probable that Fermat's "demonstratio mirabilis sane" of the general theorem was entirely different from that which he has incidentally given of the particular case.

The impossibility of the equation $x^n+y^n+z^n=0$ for $n=5$ was first demonstrated by Legendre (Mémoires de l'Académie des Sciences, 1823, vol. vi. p. 1, or Théorie des Nombres, vol. ii. p. 361. See also an earlier paper by Lejeune Dirichlet, Crelle, vol. iii. p. 354, with the addition at p. 368, and a later one by M. Lebesgue, Liouville, vol. viii. p. 49); for $n=14$, by Dirichlet (Crelle, vol. ix. p. 390); and for $n=7$, by M. Lamé (Mémoires des Savans Etrangers, vol. viii. p. 421, or Liouville, vol. v. p. 195. See also the Comptes Rendus, vol. ix. p. 359, and a paper by M. Lebesgue, Liouville, vol. v. pp. 276 & 348). But the methods employed in these researches are specially adapted to the particular exponents considered, and do not seem likely to supply a general demonstration. The proof in Barlow's Theory of Numbers, pp. 160–169, is erroneous, as it reposes (see p. 168) on an elementary proposition (cor. 2, p. 20) which is untrue. A memoir by M. Kummer on the equation $x^{2\lambda}+y^{2\lambda}=z^{2\lambda}$, in which complex numbers are not employed, and in which no single case of the theorem is may write the equation in the symmetrical form $x^\lambda+y^\lambda+z^\lambda=0$. The impossibility of solving this equation has been demonstrated by M. Kummer, first, for all values of λ not included among the exceptional primes*; and secondly, for all exceptional primes which satisfy the three following conditions:—

(1.) That the first factor of H, though divisible by λ, is not divisible by λ^2 (see art. 50).

(2.) That a complex modulus can be assigned, for which a certain definite complex unit is not congruous to a perfect λth power.

(3.) That $B_{\kappa\lambda}$ is not divisible by λ^3, B_κ representing that Bernoullian number $[\kappa \leqq \mu-1]$ which is divisible by λ†.

Three numbers below 100, viz. 37, 59, 67, are, as we have seen, exceptional primes. But it has been ascertained by M. Kummer that the three conditions just given are satisfied in the case of each of those numbers; so that the impossibility of Fermat's equation has been demonstrated for all values of the exponent up to 100. Indeed, it would probably be difficult to find an exceptional prime not satisfying the three conditions, and consequently excluded from M. Kummer's demonstration.

We must confine ourselves here to an indication of the principles on which the demonstration rests in the case of the non-exceptional primes‡.

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demonstrated (Crelle, vol. xvii. p. 203), is nevertheless of great interest for the number of auxiliary propositions contained in it. Of the same character are the notes by MM. Lebesgue and Liouville, in Liouville's Journal, vol. v. pp. 184 & 360, and a few theorems given without demonstration by Abel, Œuvres, vol. ii. p. 264.

In the year 1847, M. Lamé presented to the Academy at Paris a memoir containing a general demonstration of Fermat's Theorem, based on the properties of complex numbers (Comptes Rendus, vol. xxiv. p. 310; Liouville, vol. xii. pp. 137 & 172). It was, however, observed by M. Liouville (Comptes Rendus, vol. xxiv. p. 315), that this demonstration is defective, as it assumes, without proof, the proposition that a complex number can be represented, and in one way only, as the product of powers of complex primes—a proposition which, as we have seen, is untrue, unless we admit ideal as well as actual complex primes. The discussion on M. Lamé's memoir attracted Cauchy's attention to Fermat's Theorem; and the 24th and 25th volumes of the Comptes Rendus contain several communications from him on the subject of complex numbers [or polynômes radicaux, as he has preferred to term them]. In the earlier papers of this series, Cauchy attempts to prove a proposition which, as we have already observed (see art. 41), is untrue for complex numbers considered generally, viz. that the norm of the remainder in the division of one complex number by another can be rendered less than the norm of the divisor (see Comptes Rendus, vol. xxiv. pp. 517, 633 & 661). Elsewhere (*ibid.* p. 579) he assumes the proposition as a hypothesis, and deduces from it conclusions which are erroneous (pp. 581, 582). But at p. 1029 he recognizes and demonstrates its inaccuracy. The results at which he arrives in his subsequent papers on the same subject are, for the most part, comprehended in M. Kummer's general theory (Comptes Rendus, vol. xxv. pp. 37, 46, 93, 132, 177). In one place, however (p. 181), he enunciates, though without demonstrating, the following important result:—

"If the equation $x^\lambda+y^\lambda+z^\lambda=0$ be resoluble, x, y, z denoting integral numbers prime to λ, the sum

$$1^{\lambda-4}+2^{\lambda-4}+3^{\lambda-4}+\ldots+\left(\frac{\lambda-1}{2}\right)^{\lambda-4}$$

is divisible by λ."

(Compare M. Kummer's memoir in the Berlin Transactions for 1857, p. 64.)

The investigation of the Last Theorem of Fermat has been twice proposed as a prize-question by the Academy of Paris—first at some time previous to 1823 (see Legendre's memoir already cited, in vol. vi. of the Mémoires de l'Académie des Sciences, p. 2), and again in 1850 (Comptes Rendus, vol. xxx. p. 263): at neither time was the prize adjudged to any of the memoirs received. On the last occasion, after several postponements of the date originally fixed for the award, the prize was ultimately, in 1857 (*ib.* vol. xliv. p. 158), conferred on M. Kummer, who had not been a competitor, for his researches on complex numbers.

* Liouville, vol. xvi. p. 488, or Crelle, vol. xl. p. 131.

† See the memoir No. 15 in the list of art. 41.

‡ When λ is not an exceptional prime, the equation $x^\lambda+y^\lambda+z^\lambda=0$ is irresoluble not only

We may suppose that λ is greater than 3, and that no two of the numbers x, y, z admit any common divisor. And first, let none of them be divisible by $1-\alpha$, α still representing a root of the equation $\frac{\alpha^\lambda-1}{\alpha-1}=0$. Since for x we may write $\alpha^s x$, we may assume that x, y, z are of the form

$$\begin{aligned} x&=a+(1-\alpha)^2\,\mathrm{X}, \\ y&=b+(1-\alpha)^2\,\mathrm{Y}, \\ z&=c+(1-\alpha)^2\,\mathrm{Z}, \end{aligned}$$

a, b, c denoting integral numbers prime to λ, which evidently satisfy the congruence $a+b+c\equiv 0$, mod λ. The equation $x^\lambda+y^\lambda+z^\lambda=0$ may then be written thus

$$(x+\alpha y)(x+\alpha^2 y)(x+\alpha^3 y)\ldots\ldots(x+\alpha^{\lambda-1} y)=-z^\lambda.$$

No two of the factors of which the left hand member is composed can have any common divisor; each of them is therefore the product of a perfect λth power by a unit; so that we may write, $x+\alpha^s y=\alpha^\rho e(\alpha) v^\lambda$, $e(\alpha)$ denoting a real unit. Since v^λ is an actual number, it follows (remembering that λ is not an exceptional prime) that v is also actual; hence v^λ is congruous, mod λ, to a certain integral number m. Eliminating $m\times e(\alpha)$ between the two congruences $x+\alpha^s y\equiv m\alpha^\rho e(\alpha)$, and $x+\alpha^{-s} y\equiv m\alpha^{-\rho} e(\alpha)$, mod λ, we find $\alpha^{-\rho}(x+\alpha^s y)-\alpha^\rho(x+\alpha^{-s} y)\equiv 0$, mod λ. For the modulus $(1-\alpha)$ this congruence is identically satisfied*. That it should be satisfied, mod $(1-\alpha)^2$, we must have the relation $(a+b)\rho\equiv bs$, mod λ; whence, putting

$$\frac{b}{a+b}\equiv k, \text{ mod } \lambda,$$

we have $\rho\equiv ks$, mod λ. Substituting this value for ρ, we find that the congruence

$$\alpha^{-ks}(x+\alpha^s y)-\alpha^{ks}(x+\alpha^{-s} y)=0$$

is identically satisfied, mod $(1-\alpha)^3$; but in order that it should be satisfied, mod $(1-\alpha)^4$, we have the condition

$$s^3 b(2k-1)(k-1)-3s(\overline{k-1}\,.\,y''+kx'')\equiv 0, \text{ mod } \lambda,$$

where x'' and y'' are the values (for $\alpha=1$) of the second derived functions of x and y with respect to α. This conditional congruence must be satisfied for every value of s; either therefore $k\equiv 1$, mod λ, or $2k\equiv 1$, mod λ. The supposition $k\equiv 1$ is inadmissible; for it implies that $a\equiv 0$, mod λ, contrary to the hypothesis. Hence we must have $2k\equiv 1$, and $a\equiv b$, or, by parity of reasoning, $a\equiv b\equiv c$, mod λ. But also $a+b+c\equiv 0$, mod λ, whence we again infer the inadmissible conclusion $a\equiv b\equiv c\equiv 0$, mod λ.

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in ordinary integral numbers, but also in any complex integers composed of λth roots of unity. The demonstration does not possess the same generality when λ is an exceptional prime satisfying the three conditions cited in the text. In this case M. Kummer has only shown that the equation $x^\lambda+y^\lambda+z^\lambda=0$ is irresoluble when we suppose that x, y, z are ordinary integral numbers prime to λ, or else complex numbers containing the binary periods $\alpha+\alpha^{-1}$, one of which has a common divisor with λ.

* Since λ is divisible by $(1-\alpha)^{\lambda-1}$, and since $\phi(\alpha)=\phi(1)+(\alpha-1)\,\phi'(1)+(\alpha-1)^2\frac{\phi''(1)}{1\,.\,2}+\ldots$, it is readily seen that, if $r\leqq\lambda-1$, the conditions for the divisibility of $\phi(\alpha)$ by $(1-\alpha)^r$ are $\phi(1)\equiv 0,\ \phi'(1)\equiv 0,\ \ldots\ldots\ \phi^{(r-1)}(1)\equiv 0$, mod λ.

Secondly, let one of the numbers x, y, z (for example, z) be divisible by $1-\alpha$; it will be convenient to consider the equation in the generalized form

$$x^\lambda+y^\lambda=\mathrm{E}(\alpha)(1-\alpha)^{m\lambda}z^\lambda, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

in which x, y, and z are all prime to $1-\alpha$, and $\mathrm{E}(\alpha)$ is any unit. We may assume that the values of x and y are of the form

$$x=a+(1-\alpha)^2\,\mathrm{X},$$
$$y=b+(1-\alpha)^2\,\mathrm{Y},$$

a and b being prime to λ, but satisfying the relation $a+b\equiv0$, mod λ. In the first place, m must be greater than 1. For since $x^\lambda\equiv a^\lambda$, and $y^\lambda\equiv b^\lambda$, mod $(1-\alpha)^{\lambda+1}$, if $x^\lambda+y^\lambda$ be divisible by $(1-\alpha)^\lambda$, $a^\lambda+b^\lambda$ is divisible by λ^2, and therefore $x^\lambda+y^\lambda$ by $(1-\alpha)^{\lambda+1}$. Again, each of the factors $x+\alpha y$, $x+\alpha^2 y$, $\dots x+\alpha^{\lambda-1}y$ is divisible once, and once only, by $1-\alpha$; whence it follows that $x+y$ is divisible by $(1-\alpha)^{m\lambda-\lambda+1}$, and that no two of the λ factors of $x^\lambda+y^\lambda$ have any other common divisor than $1-\alpha$. Hence the λ factors

$$\frac{x+y}{(1-\alpha)^{m\lambda-\lambda+1}}, \qquad \frac{x+\alpha y}{1-\alpha}, \dots\dots \frac{x+\alpha^{\lambda-1}y}{1-\alpha}$$

are relatively prime, and may be represented by expressions of the form

$$e_0(\alpha)\phi_0{}^\lambda, \quad e_1(\alpha)\phi_1{}^\lambda, \dots\dots e_{\lambda-1}(\alpha)\phi_{\lambda-1}{}^\lambda,$$

$e_0(\alpha)$, $e_1(\alpha)$, ... representing units, and $\phi_0{}^\lambda$, $\phi_1{}^\lambda$, ... λth powers prime to $1-\alpha$. Eliminating x and y from the three equations

$$x+y\ \ =e_0(\alpha)(1-\alpha)^{m\lambda-\lambda+1}\phi_0{}^\lambda,$$
$$x+\alpha^r y=e_r(\alpha)(1-\alpha)\phi_r{}^\lambda,$$
$$x+\alpha_s y=e_s(\alpha)(1-\alpha)\phi_s{}^\lambda,$$

we obtain a result of the form

$$\phi_r{}^\lambda+\epsilon(\alpha)\phi_s{}^\lambda=\mathrm{E}_1(\alpha)(1-\alpha)^{(m-1)\lambda}\phi_0{}^\lambda, \quad . \quad . \quad . \quad (2)$$

$\epsilon(\alpha)$ and $\mathrm{E}_1(\alpha)$ denoting two units. But, as in the former case, it may be shown that $\phi_r{}^\lambda$ and $\phi_s{}^\lambda$ are congruous, mod λ, to real integers, and $(1-\alpha)^{(m-1)\lambda}\equiv0$, mod λ, because $m>1$. Hence $\epsilon(\alpha)$ is also congruous to a real integer for the modulus λ, and is therefore a perfect λth power by a property of every non-exceptional prime (see art. 52). The equation (2) therefore assumes the form

$$x_1{}^\lambda+y_1{}^\lambda=\mathrm{E}_1(\alpha)z_1{}^\lambda(1-\alpha)^{(m-1)\lambda}.$$

If, therefore, the proposed equation (1) be possible, it will follow, by successive applications of this reduction, that the equation

$$x^\lambda+y^\lambda=\mathrm{E}(\alpha)(1-\alpha)^\lambda z^\lambda$$

is also possible. But this equation has been shown to be impossible; the equation (1) is therefore also impossible.

62. *Application to the Theory of Numerical Equations.*—In the Monatsberichte for June 20, 1853 (see also the Monatsberichte for 1856, p. 203), M. Kronecker has enunciated the following theorem:—

"The roots of any Abelian equation, the coefficients of which are integral numbers, are rational functions of roots of unity." The demonstration of this theorem (Monatsberichte for 1853, p. 371–373) depends on a comparison of a certain form, of which the resolvent function of any Abelian equation is susceptible, with M. Kummer's expression for the resolvent function in the case of the equation of the division of the circle (see art. 60). It thus involves considerations relating to ideal numbers.

Two propositions of a more special character, and closely connected with one another, have also been given by M. Kronecker (Crelle, vol. liii. p. 173). Their demonstration is immediately deducible from the principles of Dirichlet's theory of complex units:—

"If unity be the analytical modulus of every root of an equation, of which the first coefficient is unity and all the coefficients are integral numbers, the roots of the equation are roots of unity."

"If all the roots of an equation (having its first coefficient unity and all its coefficients integral) be real and inferior in absolute magnitude to 2, so that they can be represented by expressions of the form $2 \cos \alpha$, $2 \cos \beta$, $2 \cos \gamma$, ... the arcs α, β, γ are commensurable with the complete circumference."

In the following proposition M. Kronecker has extended a theorem of M. Kummer's (art. 42) relating to complex units composed with roots of unity of which the index is a prime, to complex units composed with any roots of unity (Crelle, vol. liii. p. 176):—

"Every complex unit composed with the roots of the equation $\omega^n = 1$, can be rendered real by multiplication with a $4n$th root of unity. If n be even, a $2n$th root will always suffice; and if n be a power of a prime, an nth root will suffice."

The demonstration of this proposition is also deducible from Dirichlet's principles.

63. *Tables of Complex Primes.*—In M. Kummer's earliest memoir on complex numbers (Liouville, vol. xii. p. 206) he has given a table of the complex factors, composed of λth roots of unity, which are contained in real primes of the form $m\lambda+1$ inferior to 1000, λ representing one of the primes 5, 7, 11, 13, 17, 19, 23. This memoir was written before M. Kummer had considered the complex factors of primes of linear forms other than $m\lambda+1$, and before he had introduced the conception of ideal numbers. The complex prime factors of real primes of those other linear forms are, therefore, not exhibited in the Table; and the five numbers of the form $23m+1$, 47, 139, 277, 461, 967, each of which contains 22 ideal factors composed of 23rd roots of unity, are represented as products of 11 actual factors (each of which contains two reciprocal ideal factors). The tentative methods by which the complex factors were discovered are explained in sect. 9 of the memoir cited. Since the full development of M. Kummer's theory, Dr. Reuschle has undertaken to complete and extend the Table. He has already given tables containing the complex prime factors of *all* real primes less than 1000, composed of 5th, 7th, 11th, 13th, 17th, 23rd, and 29th roots of unity, together with the complete solution of the congruences corresponding to the equations of the periods (see the Monatsberichte for 1859, pp. 488 and 694, and for 1860, pp. 150 and 714). For 5, 7, 11, 13, 17, the complex primes are exhibited in a primary form; for 19, 23, and 29 they are exhibited in a form which satisfies the condition $f(\alpha) \equiv f(1)$, mod $(1-\alpha)^2$, but not the condition $f(\alpha) f(\alpha^{-1}) \equiv [f(1)]^2$, mod λ. The ideal factors Dr. Reuschle represents by their lowest actual powers; for 23 this power is the cube, for 29 it is the square; for 11, 13, 17, 19, as well as for 5 and 7, all complex prime factors of real primes less than 1000 are actual. It appears from the Table (and it has indeed been proved by M. Kummer), that 29 is an "irregular determinant" (see art. 49, note); for the number of classes is

8, while the square of every ideal number (occurring as a factor of a real prime inferior to 1000) is actual. The methods employed by Dr. Reuschle in the calculation of his tables have not yet been published by him. In some instances, as M. Kummer has observed, they have not led him to the simplest possible forms of the ideal primes.

A particular investigation relating to the ideal factors of 47, composed of 23rd roots of unity, has been given by Mr. Cayley (Crelle, vol. lv. p. 192, and lvi. p. 186).

64. The investigations relating to Laws of Reciprocity, which have so long occupied us in this report, have introduced us to considerations apparently so remote from the theory of the residues of powers of integral numbers, that it requires a certain effort to bear in mind their connexion with that theory. It will be remembered that the complex numbers to which our attention has been directed are not of that general kind to which we have referred in art. 41, but are exclusively those which are composed of roots of unity. The theory of complex numbers, in the widest sense of that term, does indeed present to us an important generalization of the theory of the residues of powers; for the theorem of Fermat (see art. 53) subsists alike for every species of complex numbers. But the complex numbers of Gauss, of Jacobi, and of M. Kummer force themselves upon our consideration, not because their properties are generalizations of the properties of ordinary integers, but because certain of the properties of integral numbers can only be explained by a reference to them. The law of quadratic reciprocity does not, as we have seen, necessarily require for its demonstration any considerations other than those relating to ordinary integers; the real prime numbers of arithmetic are here the ultimate elements that enter into the problem. But when we come to binomial congruences of higher orders, we find that the true elements of the question are no longer real primes, but certain complex factors, composed of roots of unity, which are, or may be conceived to be, contained in real primes. For we find that the law which expresses the mutual relation (with respect to the particular kind of congruences considered) of two of these complex factors is a primary and simple one; while the corresponding relations between the real primes themselves are composite and derivative, and, in consequence, complicated. It thus becomes indispensable, for the investigation of the properties of real numbers, to construct an arithmetic of complex integers; and this is what has been accomplished by the researches, of which an account has been given in the preceding articles.

The higher laws of reciprocity (like that of quadratic residues) may be considered as furnishing a criterion for the resolubility or irresolubility of binomial congruences; and this, though not the only application of which they are susceptible, is that which most naturally suggests itself. When the binomial congruence is cubic or biquadratic, it is easy to resolve the real prime modulus into factors of the form $a+b\rho$, or $a+bi$ (arts. 37 and 24), and equally easy to determine the value of the critical symbol of reciprocity by a uniform and elementary process (see art. 36). For these, therefore, as well as for quadratic congruences, the criterion deducible from the laws of reciprocity is all that can be desired. But for binomial congruences of higher orders this criterion is not a satisfactory one, because of the difficulty of obtaining the resolution of a real prime into its complex factors, and also because of the impossibility of determining the value of the critical symbol by the conversion of an ordinary fraction into a continued fraction.

The only known criterion applicable to such congruences is the following, the demonstration of which is deducible from the elements of the theory of the residues of powers:—Let $x^n \equiv A$, mod p, represent the proposed congruence; it will be resoluble or irresoluble according as the index of A is or is not divisible by d, the greatest common divisor of n and $p-1$, *i.e.* according as the exponent to which A appertains is or is not a divisor of $\frac{p-1}{d}$ (see arts. 14 and 15).

65. *Solution of Binomial Congruences.*—We now come to the problem of the actual solution of binomial congruences—a subject upon which our knowledge is confined within very narrow limits.

When a table of indices for the prime p has been constructed, the resolution of every binomial congruence, if it be resoluble, or, if not, the demonstration of its irresolubility, is implicitly contained in it. But to use a table of indices for the solution of a binomial congruence is, as we have already observed in a similar case (art. 16), to solve a problem by means of a recorded solution of it. When the congruence $x^n \equiv A$, mod p, is resoluble, its solution may always be made to depend on that of a congruence of the form $x^d \equiv a$, mod p, where d is the greatest common divisor of n and $p-1$, and where $a \equiv A^s$, mod p, and $ns \equiv d$, mod $p-1$. We may therefore suppose that, in the congruence $x^n \equiv A$, mod p, n is a divisor of $p-1$. This congruence (if resoluble at all) will have as many roots as it has dimensions; if ξ be any one of them, and $1, \theta_1, \theta_2, \dots \theta_{n-1}$ be the roots of the congruence $x^n \equiv 1$, mod p, the roots of $x^n \equiv A$, mod p, will be $\xi, \xi\theta_1, \xi\theta_2, \dots \xi\theta_{n-1}$; so that the complete resolution of the congruence $x^n \equiv A$, mod p, requires, first, the determination of a single root of that congruence itself, and, secondly, the complete resolution of the congruence $x^n \equiv 1$, mod p. With regard to the first of these requisites, in the important case in which the exponent t to which A appertains is prime to n, a value of x satisfying the congruence $x^n \equiv A$, mod p, can be determined by a direct method (Disq. Arith. arts. 66, 67). For, in this case, it will always happen that one value of x is a certain power A^k of A, where k is determined by the congruence $kn \equiv 1$, mod t. Nor is it necessary, in order to determine k, to know the exponent t to which A appertains; it is sufficient to have ascertained that it is prime to n; for, if we resolve $p-1$ into two factors prime to one another, and such that one of them is divisible by n and contains no prime not contained in n, the other will be divisible by t, and may be employed as modulus instead of t in the congruence $kn \equiv 1$, mod t. When this method is inapplicable, we can only investigate a root of the congruence $x^n \equiv A$, mod p (where A is different from 1), by tentative processes, which, however, admit of certain abbreviations (Disq. Arith. arts. 67, 68). The work of Poinsot (Réflexions sur la Théorie des Nombres, cap. iv. p. 60) contains a very full and elegant exposition of the theory of binomial congruences; but neither he nor any other writer subsequent to Gauss has been able to add any other direct method to that which we have just mentioned.

66. *Solution of the Congruence $x^n \equiv 1$, mod p.*—When a single root of the congruence $x^n \equiv A$ is known, we may, as we have seen, complete its resolution by obtaining all the roots of the congruence $x^n \equiv 1$, mod p. The methods of Gauss, Lagrange, and Abel for the solution of the binomial equation $x^n - 1 = 0$ are in a certain sense applicable to binomial congruences of this special form. It is evident, from a comparison of several passages in the Disquisitiones Arithmeticæ[*], that Gauss himself contemplated this arithmetical application of his theory of the division of the circle, and that he intended to include it in the 8th section of his work, which, however, has never been given to the world. In fact, the method of Abel[†] which comprehends that

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[*] See Disq. Arith. arts. 61, 73, and especially art. 335.

[†] See Abel's memoir, "Sur une classe particulière d'équations résolubles algébriquement,"

of Gauss, and which gives the solution of any Abelian equation, is equally applicable to any *Abelian* congruence; *i. e.* to any completely resoluble congruence of order m, the m roots of which (considered with regard to the prime modulus p) may be represented by the series of terms

$$r,\ \phi(r),\ \phi^2(r)\ldots\ldots\phi^{m-1}(r),$$

the symbol ϕ denoting a given rational [fractional or integral] function. And as we can always express the roots of an Abelian equation by radicals (*i. e.* by the roots of equations of two terms), so also the solution of an Abelian congruence depends ultimately on the solution of binomial congruences. When, for any prime modulus, an Abelian equation admits of being considered as an Abelian congruence, so precise is the correspondence of the equation and the congruence, that (as Poinsot has observed in a memoir in which he has occupied himself with the comparative analysis of the equation $x^n=1$, and the congruence $x^n\equiv 1$, mod p[*]) we may consider the analytical expression of the roots of the equation as also containing an expression of the roots of the congruence; and by giving a congruential interpretation[†] to the radical signs which occur in that expression, we may elicit from it the actual values of the roots of the congruence. An example taken from Poinsot's memoir will render this intelligible[‡]. The six roots of the equation $\frac{x^7-1}{x-1}=0$ are comprised in the formula

$$x=\frac{-1+\sqrt{-7}}{6}+\frac{1}{3}\left[7-\frac{1}{2}\sqrt{-7}+\frac{3}{2}\sqrt{21}\right]^{\frac{1}{3}}+\frac{1}{3}\left[7-\frac{1}{2}\sqrt{-7}-\frac{3}{2}\sqrt{21}\right]^{\frac{1}{3}},$$

where the signs + and − are to be successively attributed to $\sqrt{-7}$, and where the product of the two cube roots is $+\sqrt{-7}$, or $-\sqrt{-7}$, according to the sign attributed to $\sqrt{-7}$. Considering the equation as a congruence with regard to the modulus 43, and observing that

$$\sqrt{-7}\equiv\pm 6,\ \text{mod } 43,\quad \sqrt{21}\equiv\pm 8,\ \text{mod } 43,$$

we obtain in the first place

$$x\equiv\frac{5}{6}+\frac{1}{3}\sqrt[3]{16}+\frac{1}{3}\sqrt[3]{-8},\ \text{mod } 43,$$

and

$$x\equiv-\frac{7}{6}+\frac{1}{3}\sqrt[3]{22}+\frac{1}{3}\sqrt[3]{-2},\ \text{mod } 43,$$

the product of the two cube roots being congruous to +6 in the first formula, and to −6 in the second; and finally, observing that

$$\begin{aligned}\sqrt[3]{16}&\equiv\ \ 21,\ -\ 3,\ -18,\ \text{mod } 43,\\ \sqrt[3]{-8}&\equiv\ \ 14,\ -\ 2,\ -12,\ \text{mod } 43,\\ \sqrt[3]{22}&\equiv -15,\ -\ 4,\ \ \ 19,\ \text{mod } 43,\\ \sqrt[3]{-2}&\equiv +\ 9,\ -20,\ +11,\ \text{mod } 43,\end{aligned}$$

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sect. 3 (Œuvres, vol. i. p. 114, or Crelle, vol. iv. p. 131), and M. Serret's Algèbre Supérieure, 26th and 27th lessons.

[*] "Sur l'Application de l'Algèbre à la Théorie des Nombres," Mémoires de l'Académie des Sciences, vol. iv. p. 99.

[†] Gauss employs the symbol $\sqrt[n]{A}$, mod p, to denote a root of the congruence $x^n\equiv A$, mod p, just as he employs the symbol $\frac{B}{A}$, mod p, to denote the root of the congruence $Ax\equiv B$, mod p. The *congruential radical* $\sqrt[n]{A}$, mod p, has of course as many values as the congruence $x^n\equiv A$, mod p, has solutions; if that congruence be irresoluble, the symbol is impossible.

[‡] See the memoir cited above, p. 125.

and attending to the limitation to which the cube roots are subject,

$$x \equiv -8,\ +11,\ +21,\ \text{or},\ -2, +4,\ +16;\ \text{mod } 43.$$

Thus the complete solution of a congruence of the sixth order is obtained by means of binomial congruences of the second and third orders only.

An essential limitation to the usefulness of this method arises from the circumstance that it does not always (or even in general) happen that (as in the example just given) each surd entering into the expression of the root becomes separately rational. For that expression may itself acquire a rational value, while certain surds contained in it continue irrational, precisely as, in the irreducible case of cubic equations, a real quantity is represented by an imaginary formula. To illustrate this point by an example, let us consider the same congruence $\frac{x^7-1}{x-1} \equiv 0$ with respect to the modulus 29‡ Here in the expression

$$x = \frac{-1+\sqrt{-7}}{6} + \frac{1}{3}\rho\left[7-\frac{1}{2}\sqrt{-7}+\frac{3}{2}\sqrt{21}\right]^{\frac{1}{3}} + \frac{1}{3}\rho^2\left[7-\frac{1}{2}\sqrt{-7}-\frac{3}{2}\sqrt{21}\right]^{\frac{1}{3}},$$

where ρ denotes a cube root of unity, we have, putting $\sqrt{-7} \equiv +14$, and $\rho=1$,

$$x \equiv \frac{13}{6} + \frac{1}{3}\left[\frac{3}{2}\sqrt{21}\right]^{\frac{1}{3}} + \frac{1}{3}\left[-\frac{2}{3}\sqrt{21}\right]^{\frac{1}{3}},\ \equiv \frac{13}{6} \equiv 7,\ \text{mod } 29,$$

the irrational cube roots disappearing of themselves. Again, putting

$$\rho = \frac{1}{2}(-1 \pm \sqrt{-3}),$$

we find

$$x \equiv 7 \pm \frac{1}{3}\sqrt{-3}\left(\frac{3}{2}\sqrt{21}\right)^{\frac{1}{3}} \equiv 7 \mp \left(\frac{1}{2}\sqrt{-7}\right)^{\frac{1}{3}}$$

$$\equiv 7 \mp (7)^{\frac{1}{3}} \equiv 7 \pm 16 \equiv -6 \text{ or } -9,$$

where every radical becomes rational of itself. Similarly taking the values $\sqrt{-7} \equiv -14$, $\rho = \frac{1}{2}(-1 \pm \sqrt{-3})$, we find $x \equiv -5$ or -13. But lastly, putting $\sqrt{-7} \equiv -14$, $\rho=1$, we find

$$x \equiv 12 + \frac{1}{3}[14+7\sqrt{2}]^{\frac{1}{3}} + \frac{1}{3}[14-7\sqrt{2}]^{\frac{1}{3}}.$$

To rationalize this expression, we have to observe that $14+7\sqrt{2}$, relatively to the modulus 29, is the cube of a complex number of similar form; in fact, we have $(14 \pm 7\sqrt{2}) \equiv (5 \pm 11\sqrt{2})^3$, mod 29, whence $x \equiv -4$. To elicit, therefore, the value of this root from the irrational formula, we are obliged to solve the cubic congruence $x^3 \equiv 14+7\sqrt{2}$, which, although of lower dimensions than the proposed congruence, is probably less easy to solve tentatively, because 29 has $29^2-1=840$ residues of the form $a+b\sqrt{2}$, and only $29-1=28$ ordinary integral residues; so that practically the method fails. Theoretically, however, the relation between the analytical expression of the equation-roots and the values of the congruence-roots is of considerable importance, and the subject would certainly repay a closer examination than it has yet received. We may add that, if m be a divisor of $p-1$, the complete solution of an Abelian congruence of order m requires only two things,—1st, the complete solution of the congruence $x^m-1\equiv 0$, mod p, and, 2ndly, the determination of a single root of a certain congruence of the form $x^m-a\equiv 0$, mod p, in which a is an ordinary integer; so that in this case (which is that of the congruence $\frac{x^7-1}{x-1}\equiv 0$, mod 43) we obtain a real, and not only an apparent reduction of the proposed congruence*.

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‡ *Ibid.* p. 132.

It should also be observed that the primitive roots of the equation $\frac{x^n-1}{x-1}=0$ furnish, when rationalized, the primitive roots of the congruence $\frac{x^n-1}{x-1}\equiv 0$, mod p. This, the only direct method that has ever been suggested for the determination of a primitive root, appears to be the same as that referred to by Gauss in the Disq. Arith. (art. 73).

Poinsot expresses the conviction that this method of rationalization is applicable to any congruence corresponding to an equation, the roots of which can be expressed by radicals†. With regard to equations of the second, third, and fourth orders this is certainly true. If, for example, the biquadratic equation $F_4(x)=0$ be completely resoluble when considered as a congruence for the modulus p, so that $F_4(x)\equiv(x-a_1)(x-a_2)(x-a_3)(x-a_4)$, mod p, it is plain that the four roots of $F(x)=0$, and the four numbers a_1, a_2, a_3, a_4 may be obtained by substituting, in the general formula which expresses the root of any biquadratic equation as an irrational function of its coefficients, the values of the coefficients of the functions $F(x)$ and $(x-a_1)(x-a_2)(x-a_3)(x-a_4)$ respectively. But these two sets of coefficients differ only by multiples of p; *i. e.* the values of a_1, a_2, a_3, a_4 can be deduced from the expressions of the roots of $F(x)=0$ by adding multiples of p to the numbers which enter into those expressions. But this reasoning ceases to be applicable to equations of an order higher than the fourth, because no general formula exists representing the roots of an equation of the fifth or any higher order. If, therefore, $F(x)=0$ be an equation of the nth order, the roots of which can be expressed by a radical formula, and which is also completely resoluble when considered as a congruence for the modulus p, so that $F(x)\equiv(x-a_1)(x-a_2)\ldots(x-a_n)$, mod p, it will not necessarily follow that the formula which gives the roots of $F(x)=0$ is also capable (when we add multiples of p to the numbers contained in it) of giving the roots of $(x-a_1)(x-a_2)\ldots(x-a_n)=0$, *i. e.* the roots of the congruence $F(x)\equiv 0$, mod p; and thus the principle enunciated by M. Poinsot is, it would seem, not rigorously demonstrated.

67. *Cubic and Biquadratic Congruences.*—The reduction of cubic congruences to binomial ones has been treated of by Cauchy (Exercices des Mathématiques, vol. iv. p. 279), and more completely by M. Oltramare (Crelle, vol. xlv. p. 314). Some cases of biquadratic congruences are also considered by Cauchy in the memoir cited, p. 286. The following criteria for the resolubility or irresolubility of cubic congruences include the results obtained by M. Oltramare, *l. c.*, and appear sufficiently simple to deserve insertion here:—

Let the given cubic congruence be

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* This will be at once evident, if we observe that when the congruence $x^m\equiv 1$, mod p, is completely resoluble, its roots may be employed to replace, in Abel's method, the roots of the equation $x^m-1=0$.

† See the memoir cited above, p. 107, and M. Libri, Mémoires de Mathématique et Physique, p. 63.

$$a\theta^3+3b\theta^2+3c\theta+d\equiv 0, \text{ mod } p,$$

p denoting a prime greater than 3, which does not divide the discriminant of the congruence; *i. e.*, the number

$$D= -a^2d^2+6abcd-4ac^3-4db^3+3b^2c^2;$$

and in connexion with the congruence consider the allied system of functions*

$$U=(a, b, c, d)\ (x, y)^3,$$
$$H=(ac-b^2, \tfrac{1}{2}(ad-bc), bd-c^2)\ (x, y)^2,$$
$$\Phi=(-a^2d+3abc-2b^3, -abd+2ac^2+b^2c, acd-2b^2d+bc^2,$$
$$ad^2-3bcd+2c^3)\ (x, y)^3,$$

which are connected by the equation

$$\Phi^2+Du^2=-4H^3;$$

let also u and ϕ denote the values of U and Φ corresponding to any given values of x and y, which do not render $H\equiv 0$, mod p. Then, if $\left(\frac{\frac{1}{3}D}{p}\right)=-1$, the congruence has always one and only one real root; if $\left(\frac{\frac{1}{3}D}{p}\right)=+1$, it has either three real roots, or none: viz., if $\left(\frac{\frac{1}{2}(\phi+u\sqrt{-D})}{p}\right)_3=+1$, it has three; if $\left(\frac{\frac{1}{2}(\phi+u\sqrt{-D})}{p}\right)_3=\rho$, or $=\rho^2$, it has none. The interpretation of the cubic symbol of reciprocity will present no difficulty if we observe that $\sqrt{-D}$, mod p, is a real integer if $p=3n+1$, *i. e.* if $\left(\frac{-3}{p}\right)=1$, and that, if $p=3n-1$, *i. e.* if $\left(\frac{-3}{p}\right)=-1$, we have $\sqrt{-D}\equiv\sqrt{-3}\times\sqrt{\tfrac{1}{3}D}\equiv(\rho-\rho^2)\sqrt{\tfrac{1}{3}D}$, mod p, so that $\sqrt{-D}$, mod p, is a complex integer involving ρ. It will however be observed that the application of the criterion requires in either case the solution of a quadratic congruence, $r^2\equiv -D$, mod p, or $r^2\equiv\tfrac{1}{3}D$, mod p.

Similar, but of course less simple, criteria for the resolubility or irresolubility of biquadratic congruences may be deduced from the known formulæ for the solution of biquadratic equations.

68. *Quadratic Congruences—Indirect Methods of Solution.*—The general form of a quadratic congruence is $ax^2+2bx+c\equiv 0$, mod p,—p denoting an uneven prime modulus, and a a number prime to p. It may be immediately reduced to the binomial form $r^2\equiv D$, mod p, by putting $r\equiv ax+b$, $D\equiv b^2-ac$, mod p. The number of its solutions is 2, 0, or 1, according as D is a quadratic residue or non-residue of p, or is divisible by p, and is therefore in every case expressed by the formula $1+\left(\frac{D}{p}\right)$.

If $p=4n+3$, and $\left(\frac{D}{p}\right)=1$, the congruence $r^2-D\equiv 0$, mod p, is satisfied by $r\equiv D^{n+1}$, and $r\equiv -D^{n+1}$, and is in fact resoluble by the direct method of art. 65. But no direct method, applicable to the case when $p=4n+1$, is at present known. Two tentative methods are proposed in the sixth section of the Disquisitiones Arithmeticæ. They are both applicable to congruences with composite as well as with prime modules. This circumstance is important, because, when the modulus is a very great number, we may not be able to tell whether it is prime or composite, and, if composite, what the primes are of which it is composed, although, when the prime divisors of a composite modulus are known, it is simplest first to solve the congruence for each of them separately, and afterwards (by a method to which we shall hereafter refer) to deduce from these solutions the solution for the given composite modulus. To apply the first of Gauss's methods, the congruence is written in the form $r^2=\mathrm{D}+\mathrm{P}y$, P denoting the modulus. If in the formula $\mathrm{V}=\mathrm{D}+\mathrm{P}y$ we substitute for y in succession all integral values which satisfy the inequality $-\frac{\mathrm{D}}{\mathrm{P}}<y<\frac{1}{4}\mathrm{P}-\frac{\mathrm{D}}{\mathrm{P}}$, and select those values of V which are perfect squares, their roots (taken positively and negatively) will give us all the solutions of the congruence. We should thus have $\mathrm{I}\frac{1}{4}\mathrm{P}$ or $1+\mathrm{I}\frac{1}{4}\mathrm{P}$ trials to make, I denoting the greatest integer contained in the fraction before which it is placed. If, however, we take any number E, greater than 2, and prime to P (it is simplest to take for E a prime, or power of a prime), of which the quadratic non-residues are $a, b, c, \ldots$, and then determine the values of $\alpha, \beta, \gamma, \ldots$ in the congruences $a\equiv \mathrm{D}+\alpha\mathrm{P}$, mod E, $b\equiv\mathrm{D}+\beta\mathrm{P}$, mod E, &c., we shall find that every value of y contained in one of the linear forms $m\mathrm{E}+\alpha$, $m\mathrm{E}+\beta$, &c., gives rise to a value of V which is a quadratic non-residue of E, and which cannot, therefore, be a perfect square; so that we may at once exclude these values of y from the series of numbers to be tried. A second *excludent* E′ may then be taken, and by its aid another set of linear forms may be determined, such that no value of y contained in them can satisfy the congruence. Thus the number of trials may be diminished as far as we please. The application of this method is still further facilitated by the circumstance that it is not necessary actually to solve the congruences $a\equiv\mathrm{D}+\alpha\mathrm{P}$, mod E, ... but only the single congruence $\mathrm{D}+\mathrm{P}y\equiv 0$, mod E (Disq. Arith. art. 322). Gauss's second method depends on the theory of quadratic forms; it supposes that the congruence is written in the form $r^2+\mathrm{D}\equiv 0$, mod P. By a tentative process (abbreviated, as in the first method, by the use of excludents) Gauss obtains all possible prime representations of P by the quadratic forms of determinant $-\mathrm{D}$; whence the complete solution of the congruence $r^2+\mathrm{D}\equiv 0$, mod P, is immediately deduced. This method involves the construction of a complete system of quadratic forms of determinant $-\mathrm{D}$, or, if the prime factors of D be known, of one *genus* of forms of that system; it becomes therefore more difficult of application as D increases, whereas the first method is not affected by the increase of D. The second method, however, especially recommends itself when P is a very great number; in fact, if we do not employ any excludent, the number of trials required by the first method varies (approximately, and when P is a great number) as P, whereas, on the same supposition, the number of trials required by the second method varies as $\sqrt{\mathrm{D}}\times\sqrt{\mathrm{P}}$.

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* See a note by Mr. Cayley in Crelle's Journal, vol. l. p. 285.

M. Desmarest (in his Théorie des Nombres) has proposed a method less scientific in its character than those of Gauss, but sometimes easily applicable in practice. He has shown that if the congruence $r^2+\mathrm{D}\equiv 0$, mod P, be resoluble, we can always satisfy the equation $m\mathrm{P}=x^2+\mathrm{D}y^2$ with a value of m inferior to $\frac{\mathrm{P}}{16}+3$, and of y not superior to 3. The demonstration of this theorem is not very satisfactory, and the number of trials that it still leaves is very great, viz. $3\left(\mathrm{I}\frac{\mathrm{P}}{16}+3\right)$.

The application of Gauss's second method is rendered somewhat more uniform, and at the same time the necessity for constructing a system of quadratic forms of determinant $-D$ is avoided by the following modification of it:—By a known property of quadratic forms, whenever the congruence $r^2+D\equiv 0$, mod P, is resoluble, the equation $mP=x^2+Dy^2$ is resoluble for some value of $m<2\sqrt{\frac{D}{3}}$. By assigning, therefore, to m all values in succession which are inferior to that limit, and which satisfy the condition $\left(\frac{m}{D}\right)=\left(\frac{P}{D}\right)$, and then obtaining (by Gauss's method) all prime representations of the resulting products by the form x^2+Dy^2, we shall have $r\equiv\pm\frac{x'}{y'}$, $r\equiv\pm\frac{x''}{y''}$, ... mod P, x', y', x'', y'' etc. denoting the different pairs of values of x and y in the equation $mP=x^2+Dy^2$.

69. *General Theory of Congruences.*—We may infer from several passages in the Disquisitiones Arithmeticæ, that Gauss intended to give a general theory of congruences of every order in the 8th section of his work, and that, at the time of its publication, he was already in possession of the principal theorems relating to the subject*. These theorems were, however, first given by Evariste Galois†, in a note published in the Bulletin de Férussac for June, 1830 (vol. xiii. p. 438), and reprinted in Liouville's Journal, vol. xi. p. 398. An account of Galois's method (completed and extended in some respects) will be found in M. Serret's Cours d'Algèbre Supérieure, leçon 25. The theory has also been independently investigated by M. Schoenemann, who seems to have been unacquainted with the earlier researches of Galois (see Crelle's Journal, vol. xxxi. p. 269, and vol. xxxii. p. 93). In several of Cauchy's arithmetical memoirs (see in particular Exercices de Mathématiques, vol. i. p. 160, vol. iv. p. 217; Comptes Rendus, vol. xxiv. p. 1117; Exercices d'Analyse et de Physique Mathématique, vol. iv. p. 87) we find observations and theorems relating to it. Lastly, in a memoir in Crelle's Journal (vol. liv. p. 1) M. Dedekind has given (with important accessions) an excellent and lucid résumé of the results obtained by his predecessors.

In the following account of the principles of this theory, the functional symbols F, ϕ, ψ, ... will represent (as in general throughout this Report) rational and integral functions having integral coefficients; we shall use p to denote a prime modulus, and x an absolutely indeterminate quantity. As we shall have to consider the functions $F(x)$, $f(x)$, $\psi(x)$, etc., only in relation to the modulus p, we shall consider two functions $F_1(x)$ and $F_2(x)$, which differ only by multiples of p, as identical, and we shall represent their identity by the congruence $F_1(x)\equiv F_2(x)$, mod p, which is equivalent to an identical equation of the form $F_1(x)=F_2(x)+p\phi(x)$. The designation "modular function," which has been introduced by Cauchy (Comptes Rendus, vol. xxiv. p. 1118) will serve (though, perhaps, not in itself very appropriate) to indicate that the function to which it is applied is thus considered in relation to a prime modulus. Since in any modular function we may omit those terms the coefficients of which are multiples of p, we shall always suppose that the coefficient of the highest power of x in the function is prime to p.

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* See Disq. Arith. art. 11 and 43.

† Galois was born October 26, 1811, and lost his life in a duel, May 30, 1832. He was consequently eighteen at the time of the publication of the note referred to in the text. His mathematical works are collected in Liouville's Journal, vol. xi. p. 381. Obscure and fragmentary as some of these papers are, they nevertheless evince an extraordinary genius, unparalleled, perhaps, for its early maturity, except by that of Pascal. It is impossible to read without emotion the letter in which, on the day before his death and in anticipation of it, Galois endeavours to rescue from oblivion the unfinished researches which have given him a place for ever in the history of mathematical science.

If $F(x) \equiv f_1(x) \times f_2(x)$, mod p, $f_1(x)$ and $f_2(x)$ are each of them said to be *divisors of* $F(x)$ *for the modulus* p, or, more briefly, modular divisors of $F(x)$, or even simply divisors of $F(x)$ when no ambiguity can arise from this elliptical mode of expression. If a be a function of order zero, *i. e.* an integral number prime to p, a is a divisor, for the modulus p, of every other modular function; so that we may consider the $p-1$ terms $a_1, a_2, a_3, \ldots a_{p-1}$, of a system of residues prime to p, as the units of this theory, and, in any set of $p-1$ *associated* functions

$$a_1 F(x), \quad a_2 F(x), \ldots . \; a_{p-1} F(x),$$

we may distinguish that one as primary in which the highest coefficient is congruous to unity (mod p).

If $F(x)$ be a function which is divisible (mod p) by no other function (except the units and its own associates), $F(x)$ is said to be a prime or irreducible function for the modulus p. And it is a fundamental proposition in this theory, that every modular function can be expressed in one way, and one way only, as the product of a unit by the powers of primary irreducible modular functions. The demonstration of this theorem depends (precisely as in the case of ordinary integral numbers) on Euclid's process for finding the greatest common divisor, which, it is easy to show, is applicable to the modular functions we are considering here. For, if $\phi_1(x)$ and $\phi_2(x)$ be two such functions [the degree of $\phi_2(x)$ being not higher than that of $\phi_1(x)$], we can always form the series of congruences

$$\phi_1(x) \equiv q_1(x)\,\phi_2(x) + r_1\,\phi_3(x), \text{ mod } p,$$
$$\phi_2(x) \equiv q_2(x)\,\phi_3(x) + r_2\,\phi_4(x), \text{ mod } p,$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

in which $r_1, r_2, \ldots$ denote integral numbers, $q_1(x), q_2(x), \ldots$ modular functions, and $\phi_3(x), \phi_4(x), \ldots .$ primary modular functions, the orders of which are successively lower and lower, until we arrive at a congruence

$$\phi_k(x) \equiv q_k(x)\,\phi_{k+1}(x) + r_k\,\phi_{k+2}(x), \text{ mod } p,$$

in which $r_k \equiv 0$, mod p. The function $\phi_{k+1}(x)$ is then the greatest common divisor (mod p) of the given functions $\phi_1(x)$ and $\phi_2(x)$; and, in particular, if $\phi_{k+1}(x)$ be of order zero, those two functions are relatively prime. We may add that, if R be the *Resultant* of $\phi_1(x)$ and $\phi_2(x)$, the necessary and sufficient condition that these functions should have a common modular divisor of an order higher than zero is contained in the congruence $R \equiv 0$, mod p*—a theorem exactly corresponding to an important algebraical proposition. From the nature of the process by which the greatest common divisor is determined, we may infer the fundamental proposition enunciated above, by precisely the same reasoning which establishes the corresponding theorem in common arithmetic. Similarly, we may obtain the solution of the following useful problem:—"Given two relatively prime modular functions A_m and A_n, of the orders m and n, to find two other functions, of the orders $m-1$ and $n-1$ respectively, which satisfy the congruence

$$A_m X_{n-1} - A_n X_{m-1} \equiv 1, \text{ mod } p."$$

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* See Cauchy, Exercices de Mathématiques, vol. i. p. 160, or M. Libri, Mémoires de Mathématique et de Physique, pp. 73, 74. But a proof of this proposition is really contained in Lagrange's Additions to Euler's Algebra (sect. 4).

The assertion that $f(x)$ is a divisor of $F(x)$, for the modulus p is for brevity expressed by the congruential formula

$$F(x) \equiv 0, \text{ mod } [p, f(x)],$$

which represents an equation of the form

$$F(x) = p\phi(x) + f(x)\psi(x).$$

Similarly the congruence $F_1(x) \equiv F_2(x)$, mod $[p, f(x)]$, is equivalent to the equation

$$F_1(x) = F_2(x) + p\phi(x) + f(x)\psi(x).$$

If $f(x)$ be a function of order m, it is evident that any given function is congruous, for the *compound* modulus $[p, f(x)]$ to one, and one only, of the p^m functions contained in the formula $a_0 + a_1 x + \ldots + a_{m-1} x^{m-1}$, in which $a_0, a_1, \ldots a_{m-1}$ may have any values from zero to $p-1$ inclusive. These p^m functions, therefore, represent a complete system of residues for the modulus $[p, f(x)]$.

A congruence $F(X) \equiv 0$, mod $[p, f(x)]$, is said to be solved when a functional value is assigned to X which renders the left-hand member divisible by $f(x)$ for the modulus p; and the number of solutions of the congruence is the number of functional values (incongruous mod $[p, f(x)]$) which may be attributed to X. The coefficients of the powers of X in the function $F(X)$ may be integral numbers or functions of x. The linear congruence $AX \equiv B$, mod $[p, f(x)]$, in which A and B denote two modular functions, is, in particular, always resoluble when A is prime to $f(x)$, mod p, and admits, in that case, of only one solution.

We shall now suppose that the function $f(x)$ in the compound modulus $[p, f(x)]$ is irreducible for the modulus p,—a supposition which involves the consequence that, if a product of two factors be congruous to zero for the modulus $[p, f(x)]$, one, at least, of those factors is separately congruous to zero for the same modulus. We thus obtain the principle (cf. art. 11) that no congruence can have more solutions, for an irreducible compound modulus, than it has dimensions. For, if $X \equiv \xi$, mod $[p, f(x)]$, satisfy the congruence $F_m(X) \equiv 0$, mod $[p, f(x)]$, we find

$$F_m(X) \equiv F_m(X) - F_m(\xi) \equiv (X - \xi) F_{m-1}(X), \text{ mod } [p, f(x)],$$

$F_{m-1}(X)$ denoting a new function of order $m-1$, whence it follows that if the principle be true for a congruence of $m-1$ dimensions, it is also true for one of m dimensions; *i. e.* it is true universally.

70. *Extension of Fermat's Theorem.*—Let θ denote any one of the $p^m - 1$ residues of the modulus $[p, f(x)]$ which are prime to $f(x)$; it may be shown, by a proof exactly similar to Dirichlet's proof of Fermat's theorem, that

$$\theta^{p^m - 1} \equiv 1, \text{ mod } [p, f(x)] \ldots\ldots\ldots\ldots\ldots \text{(A)}$$

This result, which is evidently an extension of Fermat's theorem, involves several important consequences.

It implies, in the first place, the existence of a theory of residues of powers of modular functions, with respect to a compound modulus, precisely similar to the theory of the residues of the powers of integral numbers with regard to a common prime modulus. A single example (taken from M. Dedekind's memoir) will suffice to show the exact correspondence of the two theories. The modular function θ is or is not a quadratic residue of $f(x)$, for the modulus p, according as it is or is not possible to satisfy the quadratic congruence $X^2 \equiv \theta$, mod $[p, f(x)]$. In the former case θ satisfies the congruence

$\theta^{\frac{1}{2}(p^m-1)} \equiv 1$, mod $[p, f(x)]$; in the latter, $\theta^{\frac{1}{2}(p^m-1)} \equiv -1$, mod $[p, f(x)]$. And, further, if θ_1 and θ_2 be two primary irreducible modular functions of the orders m and n respectively, and if we use the symbols $\left[\frac{\theta_1}{\theta_2}\right]$ and $\left[\frac{\theta_2}{\theta_1}\right]$ to denote the positive or negative units which satisfy the congruences $\theta_1^{\frac{1}{2}(p^n-1)} \equiv \left[\frac{\theta_1}{\theta_2}\right]$, mod (p, θ_2), and $\theta_2^{\frac{1}{2}(p^m-1)} \equiv \left[\frac{\theta_2}{\theta_1}\right]$, mod (p, θ_1), respectively, these two symbols are connected by the law of reciprocity $\left[\frac{\theta_1}{\theta_2}\right] = (-1)^{mn} \left[\frac{\theta_2}{\theta_1}\right]$.

But the equation (A) admits also of an immediate application to the theory of ordinary congruences with a simple prime modulus.

In that equation let us assign to θ the particular value x; we conclude that the function $x^{p^m-1}-1$, is divisible for the modulus p by $f(x)$, *i. e.* by every irreducible modular function of order m. Further, if d be a divisor of m, $x^{p^m-1}-1$ is algebraically divisible by $x^{p^d-1}-1$; whence it appears that $x^{p^m-1}-1$ is divisible, for the modulus p, by every function of which the order is a divisor of m. But it is easily shown that $x^{p^m-1}-1$ is not divisible (mod p) by any other modular function, and that it cannot contain any multiple modular factors. Hence we have the indeterminate congruence

$$x^{p^m-1}-1 \equiv \Pi f(x), \text{ mod } p, \quad \ldots\ldots\ldots\ldots\ldots \text{(B)}$$

in which $f(x)$ denotes any primary and irreducible function, the order of which is a divisor of m, and the sign of multiplication Π extends to every value of $f(x)$. This theorem, again, is a generalization of Lagrange's indeterminate congruence (art. 10). We may infer from it that, when m is >1, the number of primary functions of order m, which are irreducible for the modulus p, is

$$\frac{1}{m}\left[p^m - \Sigma p^{\frac{m}{q}} + \Sigma p^{\frac{m}{q_1 q_2}} - \Sigma p^{\frac{m}{q_1 q_2 q_3}} + \ldots\right],$$

$q_1, q_2, \ldots$ denoting the different prime divisors of m. As this expression is always different from zero, it follows that there exist functions of any given order, which are irreducible for the modulus p.

A congruence $F(x) \equiv 0$, mod p, may be considered resolved when we have expressed its left-hand member as a product of irreducible modular factors. The linear factors (if any) then give the real solutions; the factors of higher orders may be supposed to represent imaginary solutions. We have already observed that even when all the modular factors of $F(x)$ are linear, we possess no general and direct method by which they can be assigned; it is hardly necessary to add that the problem of the direct determination of modular factors of higher orders than the first, presents even greater difficulties. Nevertheless the congruence (B) enables us to advance one step toward the decomposition of $F(x)$ into its irreducible factors; for, by means of it, we can separate those divisors of $F(x)$ which are of the same order, not, indeed, from one another, but from all its other divisors. We may first of all suppose that $F(x)$ is cleared of its multiple factors, which may be done, as in algebra, by investigating the greatest common divisor of $F(x)$ and $F'(x)$ for the modulus p. The greatest common divisor (mod p) of $F(x)$ and $x^{p-1}-1$ will then give us the product of all the linear modular factors of $F(x)$; let $F(x)$ be divided (mod p) by that product, and let the quotient be $F_1(x)$; the greatest common divisor (mod p) of $F_1(x)$ and $x^{p^2-1}-1$ will give us the product of the irreducible quadratic factors of $F(x)$;

and by continuing this process, we shall obtain the partial resolution of $F(x)$ to which we have referred.

71. *Imaginary Solutions of a Congruence.*—We have said that the non-linear modular factors of $F(x) \equiv 0$, mod p, may be considered to represent imaginary solutions. These imaginary solutions can be actually exhibited, if we allow ourselves to assign to x certain complex values. The following proposition, which shows in what manner this may be effected, is due to Galois:—

"If $f(x)$ represent an irreducible modular function of order m, the congruence

$$F(\theta) \equiv 0, \text{ mod } [p, f(x)],$$

is completely resoluble when $F(x)$ is an irreducible modular function of order m, or of any order the index of which is a divisor of m."

To establish this theorem, write θ for x in equation (B); we find $\theta^{p^m-1}-1 \equiv \Pi\, F(\theta)$, mod p, the sign of multiplication Π extending to every irreducible modular function having m or a divisor of m for the index of its order. But the congruence $\theta^{p^m-1} \equiv 1$, mod $[p, f(x)]$, admits of as many roots as it has dimensions; therefore also every divisor of $\theta^{p^m-1}-1$, and, in particular, the function $F(\theta)$ considered as a congruence for the same compound modulus, admits of as many roots as it has dimensions.

Let the order of the congruence $F(\theta) \equiv 0$, mod $[p, f(x)]$, be δ, and let any one of its roots be represented by r; it may be shown that all its roots are represented by the terms of the series $r, r^p, r^{p^2}, \ldots r^{p^{\delta-1}}$. For, if $F(r) \equiv 0$, mod $[p, f(x)]$, we have also $F(r^p) \equiv [F(r)]^p \equiv 0$, mod $[p, f(x)]$, and similarly $F(r^{p^2}) \equiv [F(r)]^{p^2} \equiv 0$, mod p; so that $r, r^p, r^{p^2}, \ldots r^{p^{\delta-1}}$ are all roots of $F(\theta) \equiv 0$, mod $[p, f(x)]$. It remains to show that these δ functions are all incongruous, mod $[p, f(x)]$. If possible let $r^{p^{k+k'}} \equiv r^{p^{k'}}$, mod $[p, f(x)]$, k and k' being less than δ; we have, raising each side of this congruence to the power $p^{\delta-k'}$, $r^{p^{\delta+k}} \equiv r^{p^\delta}$, mod $[p, f(x)]$, *i. e.* $r^{p^k} \equiv r$, or $r^{p^k-1} \equiv 1$, mod $[p, f(x)]$, observing that $r^{p^\delta} \equiv r$, mod $[p, f(x)]$, because $r^{p^\delta-1}-1$ is divisible by $F(r)$ for the modulus p. We conclude, therefore, that r is a root, mod $[p, f(x)]$, of some irreducible modular divisor of the function $\theta^{p^k-1}-1$, *i. e.* of some irreducible function of an order lower than δ, because k is less than δ; r is therefore a root, mod $[p, f(x)]$, of two different irreducible modular functions, which is impossible.

If, therefore, we suppose x to represent, not an indeterminate quantity, but a root of the equation $f(x)=0$, we may enunciate Galois' theorem as follows:—

"Every irreducible congruence of order m is completely resoluble in complex numbers composed with roots of any equation which is irreducible for the modulus p, and which has m or a multiple of m for the index of its order.

"And all its roots may be expressed as the powers of any one of them."

72. *Congruences having Powers of Primes for their Modules.*—It remains for us to advert to the theory of congruences with composite modules—a subject to which (if we except the case of binomial congruences) it would seem that the attention of arithmeticians has not been much directed. We shall suppose, first, that the modulus is a power of a prime number.

The theorem of Lagrange (art. 11), and the more general proposition of art. 69, in which it is (as we have seen) included, cannot be extended to congruences having powers of primes for their modules.

Let the proposed congruence be $F(x) \equiv 0$, mod p^m; and let us suppose (what is here a restriction in the generality of the problem) that the coefficient of the highest power of x in $F(x)$ is prime to p, or, which comes to the same thing, that it is unity. Let $F(x) \equiv P \times Q \times R \ldots \bmod p$,—$P, Q, R, \ldots$ being powers of different irreducible modular functions. It may then be shown that $F(x) \equiv P' \times Q' \times R' \ldots$, mod p^m, where $P', Q', R', \ldots$ are functions of the same order as $P, Q, R, \ldots$, respectively congruous to them for the modulus p, and deducible from them by the solution of linear congruences only. We have thus the theorem that $F(x)$, considered with respect to the modulus p^m, can always be resolved in one way and in one way only, into a product of modular functions, each of which is relatively prime (for the modulus p) to all the rest, and is congruous (for the same modulus p) to a power of an irreducible function. We may therefore replace the congruence $F(x) \equiv 0$, mod p^m, by the congruences $P' \equiv 0$, mod p^m, $Q' \equiv 0$, mod p^m, $R' \equiv 0$, mod $p^m, \ldots$ But no general investigation appears to have been given of the peculiarities that may be presented by a congruence of the form $P' \equiv 0$, mod p^m, in the case in which P is a power of an irreducible function (mod p), and not itself such a function—a supposition which implies that the discriminant of $F(x)$ is divisible by p. If, however, P be itself an irreducible function, the congruence $P' \equiv 0$, mod p_m, gives us one and only one solution of the given congruence if P be linear, or, if P be not linear, it may be considered as representing as many imaginary solutions as it has dimensions. In particular, if we consider the case in which all the divisors $P, Q, R, \ldots$ are linear, we obtain the theorem:—

"Every congruence which considered with respect to the modulus p has as many *incongruous* solutions as it has dimensions, is also completely resoluble for the modulus p^m, having as many roots as it has dimensions, and no more."

If $x \equiv a_1$, mod p, be a solution of the congruence $F(x) \equiv 0$, mod p, and if that congruence have no other root congruous to a_1, the corresponding solution $x \equiv a_m$, mod p^m, of the congruence $F(x) \equiv 0$, mod p^m, may be obtained by the solution of linear congruences only—a proposition which is included in a preceding and more general observation. The process is as follows:—If, in the equation

$$F(a_1+kp)=F(a_1)+kpF'(a_1)+\frac{k^2p^2}{1.2}F''(a_1)+\ldots,$$

we determine k by the congruence $\frac{1}{p}F(a_1)+kF'(a_1) \equiv 0$, mod p, (which is always possible because the hypothesis that $(x-a_1)^2$ is not a divisor of $F(x)$, mod p, implies that $F'(a_1)$ is not divisible by p*), and then put $a_2 \equiv a_1+kp$, mod p^2, we have $F(a_2) \equiv 0$, mod p^2. Similarly, from the expansion

$$F(a_2+kp^2)=F(a_2)+kp^2F'(a_2)+\ldots,$$

a value of k may be deduced which satisfies the congruence $F(a_2+kp^2) \equiv 0$, or $F(a_3) \equiv 0$, mod p^3; and so on continually until we arrive at a congruence of the form $F(a_m) \equiv 0$, mod p^m. But when $F(x)$ is divisible (for the modulus p) by $(x-a)^2$ or a higher power of $x-a$, the congruence $F(x) \equiv 0$, mod p^m, is either irresoluble or has a plurality of roots incongruous for the modulus p^m, but all congruous to a for the modulus p. Thus the congruence $(x-a)^2+kp(x-b) \equiv 0$, mod p^2, is irresoluble, unless $a \equiv b$, mod p; whereas if that condition be satisfied, it admits of p incongruous solutions, comprised in the formula $x \equiv a+\mu p$, mod p^2, $\mu=0, 1, 2, 3, \ldots p-1$.

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* If $F(x) \equiv (x-a_1)\,\phi(x)$, mod p, where $\phi(a_1)$ is not divisible by p, we have $F'(x) \equiv \phi(x)+(x-a_1)\,\phi'(x)$, mod p, or $F'(a_1) \equiv \phi(a_1)$, mod p.

73. *Binomial Congruences having a Power of a Prime for their Modulus.*—If M be any number, and $\psi(\mathrm{M})$ represent the number of terms in a system of residues prime to M, it will follow (from a principle to which we have already frequently referred: see arts. 10, 26, 53, 70) that every residue of that system satisfies the congruence $x^{\psi(\mathrm{M})} \equiv 1$, mod M,—a proposition which is well known as Euler's generalization of Fermat's theorem *. In particular, when $\mathrm{M}=p^m$, we have $x^{p^{m-1}(p-1)} \equiv 1$, mod p^m. This congruence has, consequently, precisely as many roots as it has dimensions—a property which is also possessed by every congruence of the form $x^d \equiv 1$, mod p^m, d denoting a divisor of $p^{m-1}(p-1)$. This has been established by Gauss in the 3rd section of the Disquisitiones Arithmeticæ, by a particular and somewhat tedious method †. The simpler and more general demonstration which he intended to give in the 8th section ‡, was perhaps in principle identical with the following; we exclude the case $p=2$, to which indeed the theorem itself is inapplicable:—

Let $d=\delta p^n$, δ representing a divisor of $p-1$, and n being $\leqq m-1$; and let us form the indeterminate congruence

$$x^\delta - 1 \equiv (x-a_1)(x-a_2)\ldots\ldots(x-a_\delta), \text{ mod } p^{m-n},$$

which is always possible, because $x^\delta - 1 \equiv 0$, mod p, has δ incongruous roots. It is readily seen that, if A and B represent two numbers prime to p, and if $\mathrm{A} \equiv \mathrm{B}$, mod p^r, $\mathrm{A}^{p^s} \equiv \mathrm{B}^{p^s}$, mod p^{r+s}; and conversely, if $\mathrm{A}^{p^s} \equiv \mathrm{B}^{p^s}$, mod p^{r+s}, $\mathrm{A} \equiv \mathrm{B}$, mod p^r §. By applying this principle it may be shown that

$$x^{\delta p^n} - 1 \equiv (x^{p^n} - a_1^{p^n})(x^{p^n} - a_2^{p^n})\ldots\ldots(x^{p^n} - a_\delta^{p^n}), \text{ mod } p^m.$$

For if we divide $x^{\delta p^n} - 1$ by $x^{p^n} - a_1^{p^n}$, the remainder is $a_1^{\delta p^n} - 1$. But, because $a_1^\delta \equiv 1$, mod p^{m-n}, $a_1^{\delta p^n} \equiv 1$, mod p^m; *i. e.* $x^{p^n} - a_1^{p^n}$ divides $x^{\delta p^n} - 1$ for the modulus p^m. Similarly $x^{\delta p^n} - 1$ is divisible (mod p^m) by $x^{p^n} - a_2^{p^n}$ etc.; and since all these divisors are relatively prime for the modulus p, $x^{\delta p^n} - 1$ is divisible (mod p^m) by their product; *i. e.*,

$$x^{\delta p^n} - 1 \equiv (x^{p^n} - a_1^{p^n})(x^{p^n} - a_2^{p^n})\ldots(x^{p^n} - a_\delta^{p^n}), \text{ mod } p^m.$$

We have thus effected the resolution of $x^{\delta p^n} - 1$ into factors relatively prime, each of which is congruous (mod p) to a power of an irreducible function; since evidently $(x^{p^n} - a^{p^n}) \equiv (x-a)^{p^n}$, mod p. To investigate the solutions of $x^{\delta p^n} - 1 \equiv 0$, mod p^m, we have therefore only to consider separately the δ congruences included in the formula $x^{p^n} \equiv a^{p^n}$, mod p^m. But each of these congruences (by virtue of the principle already referred to) admits precisely p^n solutions, viz. the p^n numbers (incongruous mod p^m) which are congruous to a, mod p^{m-n}. The whole number of solutions of $x^{\delta p^n} - 1 \equiv 0$, mod p^m, is therefore equal to the index δp^n of the congruence. It further appears that the complete solution of the binomial congruence $x^{\delta p^n} - 1 \equiv 0$, may be obtained by a direct method, when the complete solution of the simpler congruence $x^\delta - 1 \equiv 0$, mod p, has been found. For we may first

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* Euler, Comment. Arith. vol. i. p. 284.

† Disquisitiones Arithmeticæ, arts. 84—88. See also Poinsot, Reflexions sur la Théorie des Nombres, cap. iv. art. 6.

‡ Disquisitiones Arithmeticæ, art. 84.

§ If $\mathrm{A} \equiv \mathrm{B}$, mod p^r, but not mod p^{r+1}, we have $\mathrm{A}=\mathrm{B}+kp^r$, where k is prime to p. Hence $\mathrm{A}^{p^s}=(\mathrm{B}+kp^r)^{p^s}=\mathrm{B}^{p^s}+k\mathrm{B}^{p^s-1}\,p^{s+r}+\mathrm{K}\,p^{s+r}$, K denoting a coefficient divisible by p; or $\mathrm{A}^{p^s} \equiv \mathrm{B}^{p^s}$, mod p^{s+r}, but not mod p^{s+r+1}, because $k\mathrm{B}^{p^s-1}$ is prime to p. This result implies the principle enunciated in the text.

(by the method given in the last article) deduce the complete solution of $x^\delta - 1 \equiv 0$, mod p^{m-n}, from that of $x^\delta - 1 \equiv 0$, mod p; and then the roots of $x^{\delta p^n} - 1 \equiv 0$, mod p^m, can be written down at once.

74. *Primitive Roots of the Powers of a Prime.*—All the elementary properties of the residues of powers, considered with regard to a modulus which is a power of a prime number, may be deduced from the theorem just proved. In particular, the demonstration of the existence and number of primitive roots (art. 12) is applicable here also; so that we have the theorem:—

"There are $p^{m-2}(p-1)\,\psi\,(p-1)$ residues prime to p^m, the successive powers of any one of which represent all residues prime to p^m." These residues are of course the primitive roots of p^m.

If γ be a primitive root of p, of the p numbers included in the formula $\gamma + kp$ (mod p^2), $p-1$ precisely will be primitive roots of p^2. For $\gamma + kp$ is a primitive root of p^2 unless $(\gamma + kp)^{p-1} \equiv 1$, mod p^2; and the congruence $x^{p-1} \equiv 1$, mod p^2, has always one, and only one, root congruous to γ for the modulus p. But every primitive root of p^2 is a primitive root of p^3, and of every higher power of p, as may be shown by an application of the principle proved in a note to the last article, or, again, by observing that every primitive root of p^{m+1} is necessarily congruous, for the modulus p^m, to some primitive root of p^m, and that there are p times as many primitive roots of p^{m+1} as of p^m. (See Jacobi's Canon Arithmeticus, Introduction, p. xxxiii; also a problem proposed by Abel in Crelle's Journal, vol. iii. p. 12, with Jacobi's answer, ibid. p. 211.)

75. *Case when the Modulus is a Power of* 2.—The powers of the even prime 2 are excepted from the demonstrations of the two last articles—in fact, if $m \overset{=}{>} 3$, 2^m has no primitive roots. Gauss, however, has shown (Disq. Arith. arts. 90, 91) that the successive powers of any number of the form $8n+3$ represent, for the modulus 2^m, all numbers of either of the forms $8n+3$ or $8n+1$; similarly all numbers of the forms $8n+5$ and $8n+1$ are represented by successive powers of any number of the form $8n+5$. If, therefore, we denote by γ any number of either of the two forms $8n+3$ or $8n+5$, we may represent all uneven numbers less than 2^m by the formula $(-1)^\alpha \gamma^\beta$, in which α is to receive the values 0 and 1, and β the values $1, 2, 3, \ldots 2^{m-2}$. A double system of indices may thus be used to replace the simple system supplied by a primitive root when such roots exist.

Tables of indices for the powers of 2, and of uneven primes inferior to 1000, have been appended by Jacobi to his Canon Arithmeticus.

76. *Composite Modules.*—No general theory has been given of the representation of rational and integral functions of an indeterminate quantity as products of modular functions with regard to a composite modulus divisible by more than one prime. And it is possible that no advantage would be gained by considering the theory of congruences with composite modules from this general point of view. A few isolated theorems relating to particular cases have, however, been given by Cauchy (Comptes Rendus, vol. xxv. p. 36, 1847). Of these the following may serve as a specimen:—

"If the congruence $F(x) \equiv 0$, mod M, admit as many roots as it has dimensions, and if, besides, the differences of these roots be all relatively prime to M, we have the indeterminate congruence

$$F(x) \equiv k\,(x-r_1)(x-r_2)(x-r_3)\ldots(x-r_n), \text{ mod M},$$

k denoting the coefficient of the highest power of x in $F(x)$."

But if, instead of considering the modular decomposition of the function $F(x)$, we confine ourselves to the determination of the real solutions of the congruence $F(x) \equiv 0$, mod M, it is always sufficient to consider the congruences

$$F(x) \equiv 0, \text{ mod A}, \ F(x) \equiv 0, \text{ mod B}, \ F(x) \equiv 0, \text{ mod C, etc.}, \dots \quad (A)$$

where $A \times B \times C \dots = M$, and A, B, C, .. denote powers of different primes. For if $x \equiv a$, mod A, $x \equiv b$, mod B, $X \equiv c$, mod C, denote any solutions of the first, second, third ... of those congruences respectively, it is evident that, if X be a number satisfying the congruences $X \equiv a$, mod A, $X \equiv b$, mod B, $X \equiv c$, mod C (and such a number can always be assigned), we shall have $F(X) \equiv 0$ for each of the modules A, B, C, .. separately, and therefore for the modulus M; and further, if the congruences (A) admit respectively $\alpha, \beta, \gamma, \dots$ incongruous solutions, the congruence $F(x) \equiv 0$, mod M, will admit $\alpha \times \beta \times \gamma \dots$ in all; for we can combine any solution of $F(x) \equiv 0$, mod A, with any solution of $F(x) \equiv 0$, mod B, and so on*.

77. *Binomial Congruences with Composite Modules.*—The investigation of the real solutions of binomial congruences depends (in the manner just stated) on the investigation of the real solutions of similar congruences the modules of which are the powers of primes. With regard to the relations by which these real solutions are connected with one another, little of importance has been added to the few observations on this subject in the Disquisitiones Arithmeticæ (art. 92). If the modulus $M = p^a q^b r^c \dots$, $p, q, r, \dots$ representing different primes, the congruence $x^{\psi(M)} \equiv 1$, mod M, possesses no primitive roots; for if n be the least common multiple of $p^{a-1}(p-1)$, $q^{b-1}(q-1)$, $r^{c-1}(r-1), \dots$, n will be less than and a divisor of $\psi(M)$. But evidently, if x be any residue prime to M, the congruence $x^n - 1 \equiv 0$ will be satisfied separately for the modules $p^a, q^b, r^c, \dots$, and therefore for the modulus M; *i. e.*, no residue exists, the first $\psi(M)$ powers of which are incongruous, mod M. If, however, $M = 2p^a$ this conclusion does not hold, since the least common multiple of $\psi(2)$ and $\psi(p^m)$ is $\psi(2p^m)$ itself; and we find accordingly that every uneven primitive root of p^m is a primitive root of $2p^m$. When, as is sometimes the case, it is convenient to employ indices to designate the residues prime to a given composite modulus, we must employ (as in the case of a power of 2) a system of multiple indices. To take the most general case, let $M = 2^\theta p^a q^b r^c \dots$; let u be any number of either of the forms $8n+3$ or $8n+5$, and P, Q, R, ... primitive roots of $p^a, q^b, r^c, \dots$ respectively. Then, if n be any given number prime to M, it will always be possible to find a set of integral numbers $\epsilon_n, \omega_n, \alpha_n, \beta_n, \gamma_n \dots$ satisfying the conditions

$$\begin{gathered}
(-1)^{\epsilon_n} u^{\omega_n} \equiv n, \text{ mod } 2^\theta; \ 0 \leqq \epsilon_n < 2, \ 0 \leqq \omega_n < 2^{\theta-2}, \\
P^{\alpha_n} \equiv n, \text{ mod } p^a; \ 0 \leqq \alpha_n < p^{a-1}(p-1), \\
Q^{\beta_n} \equiv n, \text{ mod } q^b; \ 0 \leqq \beta_n < q^{\ -1}(q-1), \\
R^{\gamma_n} \equiv n, \text{ mod } r^c; \ 0 \leqq \lambda_n < r^{c-1}(r--1); \\
\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot
\end{gathered}$$

and these numbers form a system of indices by which the residue of n for each of the modules $2^\theta, p^a, q^b, r^c, \dots$ (and consequently for the modulus M) is completely determined. (See Dirichlet's memoir on the Arithmetical Progression, sect 7, in the Berlin Memoirs for 1837.)

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* "Infra [*i. e.* in the 8th section] congruentias quascumque secundum modulum e pluribus primis compositum, ad congruentias quarum modulus est primus aut primi potestas reducere, fusius docebimus" (Disq. Arith. art. 92). It is difficult to see why Gauss should have employed the word "fusius" if his investigation extended no further than the elementary observations referred to in the text. Nevertheless it is remarkable that Gauss in the 3rd section of the Disq. Arith. sometimes speaks of demonstrations as obscure, which are of extreme simplicity when compared with one in the 4th and several in the 5th section (see in particular arts. 53, 55, 56).

78. *Primitive Roots of the Powers of Complex Primes.*—Dirichlet has shown[*] that, in the theory of complex numbers of the form $a+bi$, the powers of primes of the second species (see art. 25) have primitive roots; in fact, if $a+bi$ be such a prime, and $\mathrm{N}\,(a+bi)=a^2+b^2=p$, every primitive root of p^m is a primitive root of $(a+bi)^m$. On the other hand, if q be a real prime of the form $4n+3$, q^m has no primitive roots in the complex theory. For in general, if M be any complex modulus, and $\mathrm{M}=a^\alpha b^\beta c^\gamma \ldots$, $a, b, c, \ldots$ being different complex primes, and if $\mathrm{A}=\mathrm{N}\,(a)$, $\mathrm{B}=\mathrm{N}\,(b)$, $\mathrm{C}=\mathrm{N}\,(c)$, etc., the number of terms in a system of residues prime to M, is $\mathrm{A}^{\alpha-1}\,(\mathrm{A}-1)\,\mathrm{B}^{\beta-1}\,(\mathrm{B}-1)\,\mathrm{C}^{\gamma-1}\,(\mathrm{C}-1)\ldots.$ And if we denote this number by $\psi\,(\mathrm{M})$, every residue prime to M will satisfy the congruence

$$x^{\psi(\mathrm{M})}\equiv 1, \text{ mod M},$$

which here corresponds to Euler's extension of Fermat's theorem. If $\mathrm{M}=q^m$, this congruence becomes $x^{q^{2m-2}(q^2-1)}\equiv 1$, mod q^m; but it is easily shown that every residue prime to q^m satisfies the congruence $x^{q^{m-1}(q^2-1)}\equiv 1$, mod q^m; *i. e.*, q^m has no primitive roots, because the exponent $q^{m-1}\,(q^2-1)$ is a divisor of, and less than, $q^{2(m-1)}\,(q^2-1)$. Nevertheless two numbers γ and γ', can always be assigned, of which one appertains to the exponent $q^{m-1}\,(q^2-1)$ and the other to the exponent q^{m-1}, and which are such that no power of either of them can become congruous to a power of the other, mod q^m, without becoming congruous to unity; from which it will appear that every residue prime to q^m may be represented by the formula $\gamma^x\,\gamma'^y$, if we give to x all values from 0 to $(q^2-1)\,q^{m-1}-1$ inclusive, and to y all values from 0 to $q^{m-1}-1$ inclusive.

The corresponding investigations for other complex numbers besides those of the form $a+bi$ have not been given.

We here conclude our account of the Theory of Congruences. The further continuation of this Report will be occupied with the Theories of Quadratic and other Homogeneous Forms.

Additions to Part I.

Art. 16. Legendre's investigation of the law of reciprocity (as presented in the 'Théorie des Nombres,' vol. i. p. 230, or in the 'Essai,' ed. 2, p. 198) is invalid only because it assumes, without a satisfactory proof, that if a be a given prime of the form $4n+1$, a prime b of the form $4n+3$ can always be assigned, satisfying the equation $\left(\frac{a}{b}\right)=-1$. M. Kummer (in the Memoirs of the Academy of Berlin for 1859, pp. 19, 20) says that this postulate is easily deducible from the theorem demonstrated by Dirichlet, that every arithmetical progression, the terms of which have no common divisor, contains prime numbers. It would follow from this, that the demonstration of Legendre (which depends on a very elegant criterion for the resolubility or irresolubility of equations of the form $ax^2+by^2+cz^2=0$) must be regarded as rigorously exact (see, however, the "Additamenta" to arts. 151, 296, 297 of the Disq. Arith.). In the introduction to the memoir to which we have just referred, the reader will find some valuable observations by M. Kummer on the principal investigations relating to laws of reciprocity.

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[*] See sect. 2 of the memoir, Untersuchungen über die Theorie der complexen Zahlen, in the Berlin Memoirs for 1841.

Art. 20. Dirichlet's demonstration of the formulæ (A) and (A′) first appeared in Crelle's Journal, vol. xvii. p. 57. Some observations in this paper on a supposed proof of the same formulæ by M. Libri (Crelle, vol. ix. p. 187) were inserted by M. Liouville in his Journal, vol. iii. p. 3, and gave rise to a controversy (in the Comptes Rendus, vol. x.) between MM. Liouville and Libri. The concluding paragraphs of Dirichlet's paper contain the application of the formulæ (A) and (A′) to the law of reciprocity (Gauss's fourth demonstration).

Art. 22. From a general theorem of M. Kummer's (see arts. 43, 44 of this Report), it appears that the congruence $r^2 \equiv (-1)^{\frac{\lambda-1}{2}}\lambda$, mod q, is or is not resoluble, according as $q^{\frac{\lambda-1}{2}} \equiv +1$, or $\equiv -1$, mod λ,—a result which implies the theorem of quadratic reciprocity. This very simple demonstration (which is, however, only a transformation of Gauss's sixth) appears first to have occurred to M. Liouville (see a note by M. Lebesgue in the Comptes Rendus, vol. li. pp. 12, 13).

Art. 24. A note of Dirichlet's, in Crelle, vol. lvii. p. 187, contains an elementary demonstration of Gauss's criterion for the biquadratic character of 2. From the equation $p=a^2+b^2$, we have $(a+b)^2 \equiv 2ab$, mod p, and hence $(a+b)^{\frac{1}{2}(p-1)} \equiv 2^{\frac{1}{4}(p-1)} a^{\frac{1}{4}(p-1)} b^{\frac{1}{4}(p-1)} \equiv (2f)^{\frac{1}{4}(p-1)} a^{\frac{1}{2}(p-1)}$, or, which is the same thing,

$$\left(\frac{a+b}{p}\right) \equiv (2f)^{\frac{1}{4}(p-1)} \left(\frac{a}{p}\right). \quad \ldots\ldots\ldots\ldots\ldots (\mathrm{A})$$

But $\left(\frac{a}{p}\right) = \left(\frac{p}{a}\right) = 1$, because $p \equiv b^2$, mod a; and $\left(\frac{a+b}{p}\right) = \left(\frac{p}{a+b}\right)$, or, observing that $2p=(a+b)^2+(a-b)^2$,

$$\left(\frac{a+b}{p}\right) = \left(\frac{2}{a+b}\right) = (-1)^{\frac{(a+b)^2-1}{8}} \equiv f^{\frac{1}{4}(p-1)+\frac{1}{2}ab},$$

since $f^2+1 \equiv 0$, mod p. Substituting these values in the equation (A), we find $2^{\frac{1}{4}(p-1)} \equiv f^{\frac{1}{2}ab}$, mod p, which is in fact Gauss's criterion.

Art. 25. In the second definition of a primary number, for "b is uneven," read "b is even." Although this definition has been adopted by Dirichlet in his memoir in Crelle's Journal, vol. xxiv. (see p. 301), yet, in the memoir "Untersuchungen über die complexen Zahlen" (see the Berlin Memoirs for 1841), sect. 1, he has preferred to follow Gauss.

Art. 36. In the algorithm given in the text, the remainders $p_2, p_3 \ldots$ are all uneven; and the computation of the value of the symbol $\left(\frac{p_0}{p_1}\right)_4$ is thus rendered independent of the formula (iii) of art. 28. The algorithm given by Eisenstein is, however, preferable, although the rule to which it leads cannot be expressed with the same conciseness, because the continued fraction equivalent to $\frac{p_0}{p_1}$ terminates more rapidly when the remainders are the least possible, and not necessarily uneven.

Art. 37. In the definition of a primary number, for "$a \equiv \pm 1$," read "$a \equiv -1$." But, for the purposes of the theory of cubic residues, it is simpler to consider the two numbers $\pm(a+b\rho)$ as both alike primary (see arts. 52 and 57).

Art. 38. Jacobi's two theorems cannot properly be said to involve the cubic law of reciprocity. If $\left(\frac{p_1}{p_2}\right)_3 = 1$, it will follow from those theorems that $\left(\frac{p_2}{p_1}\right)_3 = 1$. But if $\left(\frac{p_1}{p_2}\right)_3 = \rho$, or ρ^2, they do not determine whether $\left(\frac{p_2}{p_1}\right)_3 = \rho$, or ρ^2. It is remarkable that these theorems, "formâ genuinâ quâ inventa sunt," may be obtained by applying the criteria for the resolubility or irresolubility of cubic congruences (art. 67) to the congruence $r^3 - 3\lambda r - \lambda M \equiv 0$, mod q (art. 43), which, by virtue of M. Kummer's theorem (art. 44), is resoluble or irresoluble according as q is or is not a cubic residue of λ.

On the Performance of Steam-Vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel. By Vice-Admiral MOORSOM.

(A communication ordered to be printed among the Reports.)

IN this the fourth paper which I now lay before the British Association, it may be desirable to recapitulate the points I have brought into issue, and for the determination of which, *data*, only to be obtained by experiments, are still wanting, viz.—

1. There is no agreed method by which the resistance of a ship may be calculated under given conditions of wind and sea.
2. The known methods are empirical, approximate only, and imply smooth water and no wind.
3. The relations in which power and speed stand to form and to size are comparatively unknown.
4. The relations in which the *direct* and *resultant* thrust stand to each other in any given screw, and how affected by the resistance of the ship, are undetermined.

In order to resolve these questions, specific experiments are needed, and none have yet been attempted in such manner as to lead to any satisfactory result.

The Steam Ship Performance Committee of the British Association have pressed upon successive First Lords of the Admiralty, the great value to the public service which must ensue if the following measures were taken, viz.—

1. To determine, by specific experiment, the resistance, under given conditions, of certain vessels, as types; and, at the same time, to measure the *thrust* of the screw.
2. To record the trials of the Queen's ships, so that the performance in smooth water may be compared with the performance at sea, both being recorded in a tabular form, comprising particulars, to indicate the characteristics of the vessel, of the engine, of the screw, and of the boiler.

Hitherto nothing has come of these representations.

In the paper read last year at Aberdeen, I showed, in the case of Lord Dufferin's yacht 'Erminia,' how the absence of admitted laws of resistance interfered with the adjustment of her screw, and how, therefore, as a matter of precaution, a screw was provided capable of a *thrust* beyond what the vessel required.

I also showed, in the case of the Duke of Sutherland's yacht 'Undine,' how her screw, from being too near the surface of the water, lost a large portion of the *thrust* due to its size and proportions. In other words, a screw capable of giving out a resultant thrust in sea water of 5022 lbs., at a speed of vessel of 9·26 knots an hour, did actually give out only 3805 lbs. That is to say, the effect produced was the same *as if* that screw had worked in a fluid whose weight was about 48 lbs. per cubic foot instead of 64 lbs.

I am now about to exhibit some other examples from among Her Majesty's ships of war.

The questions now before us are—

1. The resistance of the hull below the water-line in passing through the water, and of the upper works, masts, rigging, &c., passing through the air, the weather being calm, and the water smooth.

2. The relation in which the *thrust* of the screw stands to this resistance.

[The Admiral here gave certain results from the 'Marlborough,' the 'Renown,' and the 'Diadem,' and proposed that a specific issue should be tried by means of the 'Diadem.']

What would I not give, he observed, for some well-conducted experiments to determine this beautiful problem of the laws which govern the action of the screw in sea-water! It is a problem not only interesting to science, but fraught with valuable results in the economical and efficient application of the screw propeller.

After commenting on the performances of the U. S. corvette 'Niagara,' the Admiral observed, I have no means of forming a very definite opinion as to how she will *stay* under low sail in a sea-way, how she will *wear*, how *scud* in a following sea, or how stand up under her sails, or whether her *statical* stability be too much or too little, or how the fore and after bodies are balanced. These are points to be determined, not by the mere opinion of seamen—for a sailor will vaunt the qualities of his ship even as a lover the charms of his mistress—but by careful records of performances in smooth water and at sea, and a comparison of such performances with calculated results from drawings *beforehand*. Let a return of such things be annually laid before the House of Commons—we shall then know whether we are getting money's worth for our money; and also we should receive all the benefits of public criticism towards improvement. We should not then allow defects to be stereotyped, till chronic blemishes are turned into beauties, or, if not so, then defended as things that cannot be remedied.

I have now completed the task which four years ago I imposed on myself. Beginning with simple elementary principles, and ending with minute practical details, I have, as I conceive, shown the process by which the improvement of steam-ships must be carried on.

More than one hundred years ago scientific men, able mathematicians, showed the physical laws on which naval architecture must rest. A succession of able men have shown how those laws affect various forms of floating bodies. Experiments have been made with models to determine the value of the resistance practically. With the exception of some experiments of Mr. Scott Russell, I am not aware that any have been made with vessels approaching the size of ships to determine the relations of resistance to power, whether wind or steam.

Ships have been improved, and modifications of form have been arrived at by a long painstaking tentative process. The rules so reached for sailing ships have been superseded by steam, and we are still following the same tedious process, in order to establish new rules for the application of steam power.

I think the history of naval architecture shows that it is not an abstract science, and that its progress must depend on the close observation and correct record of facts; on the careful collating, and scientific comparing of such facts, with a view to the induction of general laws. Now, is there anywhere such observing, recording, collating, and comparing? and still more, is there such inducting process?

I can find no such thing anywhere in such shape that the public can judge it by its fruits.

We are now in full career of a competition of expenditure, and England has no reason to flinch from such an encounter, unless her people should tire of paying a premium of insurance upon a contingent event that never may happen; and if it should happen without our being insured, might not cost as much as the aggregate premiums. Tire they will, sooner or later, but they are more likely to continue to pay in faith and hope, if they had some confidence that their money is not being spent unnecessarily.

There is now building at Blackwall the 'Warrior,' a ship to be cased with 4½-inch plates of iron, whose length at water-line is 380 feet, breadth 58 feet, intended draught of water (mean) 25½ feet, area of section 1190 square feet, and displacement about 8992 tons, and she is to have engines of 1250 nominal horse-power.

Is there any experience respecting the qualities and performance of such a ship? Anything to guide us in reasoning from the known to the unknown? Do the performances of the 'Diadem,' 'Mersey,' and 'Orlando,' inspire confidence? Where are the preliminary experiments?

Before any contract was entered into for the construction of the Britannia Bridge, a course of experiments was ordered by the Directors, which cost not far short of £7000, and it was well expended. It saved money, and perhaps prevented failure. This ship must cost not less than £400,000, and may cost a good deal more when ready for sea. But there is another of similar, and two others building, of smaller size. What security is there for their success?

The conditions which such a ship as the 'Warrior' must fulfil in order to justify her cost are deserving of some examination. The formidable nature of her armament, as well as her supposed impregnability to shot, will naturally lead other vessels to avoid an encounter. She must therefore be of greater speed than other ships of war. To secure this, it is essential that her draught of water should be the smallest that is compatible both with *stability* and *steadiness* of motion, and that she *should not be deeper than the designer intended.* To ensure steadiness it is necessary, among other things, that in rolling, the solids, emerged and immersed, should find their axis in the longitudinal axis of the ship. To admit of accurate aim with the guns, her movement in rolling should be slow and not deep. Every seaman knows how few ships unite these requisites.

It is not quite safe to speculate on the 'Warrior's' speed; nevertheless I will venture on an estimate, such as I have stated in the case of the 'Great Eastern,' whose smooth-water speed I will now assume to be 15¾ knots, as before estimated, with 7732 horse-power, when her draught of water is 28 feet, her area of section, say 1650 square feet, and her displacement about 18,588 tons. The speed of the 'Warrior' in smooth water ought not to be less than 16 knots, in order that she may force to action unwilling enemies whose speed may be 13 to 14 knots.

The question I propose is the power to secure a smooth-water speed of 16 knots.

Reducing the 'Great Eastern' to the size of the 'Warrior,' and applying the corrections for the difference of speed of ¼ knot, and for their respective coefficients of specific resistance ·0564 and ·07277, the horse-power for 16 knots is 7543.

Raising the 'Niagara' to the size of the 'Warrior,' and applying the corrections for the difference of speed between 10·9 and 16 knots, and for their respective coefficients of specific resistance ·0797 and ·07277, the horse-power to give the 'Warrior' a smooth-water speed of 16 knots is 7867, being an excess over the estimate from the 'Great Eastern' of 324 horse-power.

If the power required for the 'Warrior' be calculated by adaptation from the 'Mersey' and the 'Diadem,' it would be 8380 horse-power and 8287 respectively; from which this inference flows:—that unless the mistakes made in the fore and after sections of the 'Mersey' and 'Diadem' are rectified in the 'Warrior,' she will require above 8000 horse-power for a speed of 16 knots, notwithstanding her greater size and increased ratio of length to breadth.

Before investing more than a million and a half of money in an experiment, commercial men would have probably employed a few thousand pounds in some sort of test as to the conditions of success. Perhaps such test may have been resorted to and kept secret for reasons of public policy. Perhaps it is intended that the 'Warrior's' speed should not be greater than that which is due to five times her nominal horse-power, which could not exceed 15½ knots with 6250 horse-power, under the most favourable conditions, and may be much less.

The British Association, by becoming the medium of collecting facts and presenting them to the public, has done good service; but that service ought not to rest there. Collectively, the Association may be able to do little more. It can only act by affording public opinion a means of expression. But individual members may do much. Towards such opinion I am doing my part.

I ask, in the cause of science, what is the system under which the Queen's ships are designed and their steam power apportioned; the organization by which their construction and fitting for sea are carried on; the supervision exercised over their proceedings at sea, in the examination of returns of performance and of expenditure?

During part of 1858 and 1859, two committees appointed by the Admiralty collected evidence and made reports on the Dock Yards and on steam machinery. I have read both reports with some attention. They are not conclusive, but they are entitled to respect. I have also read the replies and objections of the Government officers. There is a clear issue between them on some of the most essential principles of effective economical management, and on the application of science.

A Royal Commission has been appointed to inquire into the system of control and management in the Dock Yards. This is so far good, but it does not go far enough. It does not comprise the steam machinery reported on by Admiral Ramsay's Committee, and it cannot enter upon the questions I have just enumerated. Yet the efficiency of the fleet depends quite as much upon the adaptation of the machinery to the ship, and of the ship to the use she is to be put to, as it does upon the manner in which she is built. The Commission ought to be enlarged both in objects and in number of members. It consists of five members only.

Report on the Effects of long-continued Heat, illustrative of Geological Phenomena. By the Rev. W. VERNON HARCOURT, *F.R.S., F.G.S.*

THE chief occupation of those who during the present century have employed themselves in investigating the history of the earth, has been to develope the succession of its *strata*. In following this pursuit, they have found their best guide in the study of its organic antiquities, and have not been led, for the most part, to very precise views of the physical and chemical changes which it has undergone.

Yet there are questions in Geology to which no answer can be given without an accurate examination into these. In regard, for example, to the chronology of the earth, the observation of organic remains alone can never supply reliable *data* for reasoning. If we should attempt to draw inferences from biological analogies, and measure the duration of beds by the growth of imbedded skeletons, we should be stopped by the probability that the first species of every series were successively created in a state of full-grown maturity*, and by the intrinsic weakness of all comparisons instituted *non pari materiâ*.

Neither can any precarious mechanical analogies render the inquiry more definite, or give a logical value to our conclusions. We are not entitled to presume that the forces which have operated on the earth's crust have always been the same. Were we to compare the beds of modern seas and lakes with the ancient strata, and assume proportionable periods for their accumulation, we must assume also that chemical and mechanical forces were never in a state of higher intensity, that water was never more rapidly evaporated, that greater torrents, fluid or gaseous, never flushed the lakes and seas, and that more frequent elevations and depressions never gave scope for quicker successions of animal life. To gain any real insight into these obscure pages of ancient history, we must have recourse to a strict induction of physical and chemical facts, and thence learn the probable course, and causes, of the wonderful series of changes which geology unfolds.

I am not aware that any full and connected statement has been published of the facts which have been contributed by physical observations, and chemical experiment, towards elucidating the conditions of those changes, and propose therefore to preface the account which I have to give of experiments designed to throw light upon them, with a sketch of the progress of science in that department.

Forty years have elapsed since the author of the 'Mécanique Céleste' drew attention to the fact that multiplied observations in deep mines, wells, and springs, had proved the existence of a temperature in the interior of the earth increasing with the depth. He remarked that, by comparing exact observations of the increase with the theory of heat, the epoch might be determined at which the gradually cooling globe had been first transported into space; he stated the mean increase, collected from actual data, to be a centesimal degree for every 32† metres, and added that this is an element of high importance to geology. "Not only," he said, "does it indicate a very great heat at the earth's surface in remote times, but if we compare it with the theory of heat, we see that at the present moment the temperature of the earth is excessive at the depth of a million of metres, and above all at the centre; so that all that part of the globe is probably in a state of fusion, and would be reduced into vapour, but for the superincumbent beds, the pressure of which, at those great depths, is immense." "These considerations," he further added, "will explain a great number of geological phenomena;" and he instanced those of hot springs, which he accounted for on the supposition that rain-water in channels communicating from superficial reservoirs with the interior of the earth, thence rises again, heated, to the surface.

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* To suppose otherwise with regard to animals which take care of their young would be absurd; and hence it is probable also that this is the general system of creation. The most remarkable fact which modern geology has disclosed is the continual succession of newly-created species. It has been attempted to account for these according to known laws of *progeniture*, by supposing numerous non-apparent links of transitional existence to fill up the gaps in the chain of derivation by which one species is presumed to have descended from another. But this is only twisting a rope of sand; conjectural interpolations cannot give coherence to a set of chains which are destitute of all evidence of continuity one with another, and between which, as far as our experience goes, Nature has interposed a principle of disconnexion.

In using the word *creation*, we acknowledge an *agent*, and own our ignorance of the *agency*, with regard to which, in this case, we only know that it is *systematic*; for we see successive species accommodated to successive conditions of existence.

† M. Babinet (Tremblements de Terre, 1856), taking M. Walferdin's measurement from artesian borings, which gave 31 metres for 1° C. as the most exact, remarks, that the temperature at the depth of 3 kilometres must be above the heat of boiling water, and at that of 60 kilometres, about 2000° C., sufficing for the fusion of lava, basalt, trachyte, and porphyry.

Fourier, at the same time, expounded the methods by which, after extended observation of the internal temperature, and further experiments on the conduction of heat, he conceived that mathematic analysis might determine the epoch at which the process of cooling began, concluding in the meanwhile from facts already known,—1st, that no sensible diminution of temperature has taken place during the period of historical chronology; 2ndly, that at a former era the temperature underwent *great and rapid changes.*

Thus was a train of graduated causes, physical and chemical, introduced into Geology on the foundation of inductive reasoning, which is capable of resolving some of the chief difficulties of the science in our comparison of the present with the past.

When, for instance, we read in the organic contents of the strata the history of a period when the climate was apparently uniform in all parts of the earth, and learn from the imbedded plants that the temperature of Arctic lands was once equal to that of warm latitudes at the present day, to account for these circumstances, we need no longer bewilder ourselves with *hypotheses*; we have a *vera causa* in the knowledge that the earth has passed through a state in which its temperature was due, not so much to a sun then veiled in clouds, as to a heat penetrating equally in all directions from the centre to the circumference of the globe.

When, again, we contemplate a mountain range, and view the abrupt precipices of some alpine chain, with its enormous masses of rock uplifted to the clouds, and descending as many miles into the bosom of the sea, and when we compare such abnormal labours of nature with the petty risings of the earth's surface in the existing state of things, we have a *vera causa* for that disparity, in the knowledge that there was a time when the eruptive forces of the seething mass within were greater, and when a weaker crust underwent vaster disturbances.

Or if we examine the general structure of the strata, and see the same *stratum* contemporaneously solidified over large portions of the earth's circumference, and then observe the absence of consolidation in the actual operations of nature, whether under the pressure of deep seas, or elsewhere, except in a few *foci* of igneous action, we have here also a *vera causa* of the difference, in the ancient prevalence of that high temperature which the laboratory of nature and art shows to be the most capable of lapidifying stony materials.

Descending into the details of mineralogy, we find the same departure from the present order of nature in the constitution of minerals; and in the sequence of chemical effects of heat increasing with the age of the *stratum*, we see a *real cause* for the distinction.

Thus, for example, to begin with the upper beds, the chemist knows that solutions of carbonate of lime, at the *ordinary* temperature, deposit crystals with the common form of *calcareous* spar, but near the *boiling*-point of water with that of *Arragonite.* Now in the mineralogical collection of the Yorkshire Philosophical Society is a specimen of this mineral investing calcite, from the *chalk* cliffs of Beachy Head; and if any one will examine the caves of *calcareous grit* on the Yorkshire coast, he will find them in some places lined, like those of volcanic rocks, or the mouths of hot springs, with

*Arragonite**. Here then we have proof of a certain *modicum* of heat existing in boiling-springs now extinct, which once pervaded these *strata*; for had the heat of the water which left this deposit been much more, or less, than about 212° F., no such crystals could have been formed. Not far from the same locality, in a thin seam of the cornbrash Oolite, I have found nodules enclosing small *Crustacea*, the interior of which was filled with crystalline *blende*. No other trace of zinc is to be seen in the country around†. The same singular phenomenon may be observed in the neighbouring Lias-shale, where the chambers of the Ammonites frequently contain *blende*‡. This is not a phenomenon peculiar to the district; it illustrates the general condition of the earth after these shells were deposited, and is best accounted for by the *vera causa* of an elevated temperature; it indicates that the fumes of zinc, or one of its volatile combinations, must have penetrated the strata, taking the form of blende in the chambers of the Ammonite, and having been sealed up in these, escaped decomposition.

The same account is applicable to the dissemination of carbonate and sulphide of lead and copper in the Permian and Triassic strata, and of the particles of metallic copper in the *mountain* limestone; as well as to the deposits of *calamine* in the hollows of that rock, on the conditions of which deposits light is thrown by an experiment of Delanoue, who found that no precipitate of carbonate of zinc is produced by limestone at the *common* temperature, but that it is perfectly thrown down from a *warm* solution of its salts.

And here also it is worthy of remark, that in the experiments of Forchhammer to illustrate the formation of dolomitic strata, when a solution of carbonate of lime was mixed with sea-water at a boiling heat, the compound formed contained only 18 per cent. of carbonate of magnesia, but that the proportion of magnesia increased with an increase of temperature; in the experiments of Favre and Marignac, the composition of equal atoms, which is that of many natural beds of magnesian limestone, was attained by raising the heat to 392° F., and the pressure to 15 atmospheres; and in those of Morlot a mixture of sulphate of magnesia and calcareous spar was completely converted, in the same circumstances, into a double salt of carbonate of lime and magnesia, with sulphate of lime.

The probable history of all the calcareous and magnesian strata, with their interstratified cherts and flints, and interspersed chalcedonic fossils, is that they are products of submarine *solfataras*, whence issued successively, in basins variously extended, gases and springs capable of dissolving preexistent beds, which caused alternate depositions of silica and carbonated earths, and intermitting from time to time, allowed intervals for the succession of organic and animated beings.

The manner in which materials are furnished for extensive sedimentary deposits by processes of disintegration dependent on subterraneous emanations, has been observed by Bunsen in the *solfataras* of Iceland. He describes the *palagonitic* rocks, formerly erupted there, as undergoing conversion by these means "into alternate and irregularly penetrating beds of white ferruginous, and coloured ferruginous, fumerole clay, the deposits being disclosed to a considerable depth, and exhibiting in the clearest manner the phenomena of alternating colours." "One is astonished," he remarks, "at observing the great similarity between the external phenomena of these metamorphic deposits of clay still in the act of being formed, and certain structures of the *Keuper* formation. Thousands of years hence the geologist who explores these regions when the last traces of the now active fumeroles have vanished, and the clay formations have become consolidated into marl-like rocks by the silica with which they are saturated, may suppose, from the differently stratified petrographic and chemical character of these beds, that he is looking at *flœtz* strata formed by deposition from water." "At the surface, especially, where the deposition is favoured by slow evaporation, innumerable crystals of gypsum, often an inch in diameter, may frequently be observed loosely surrounded by an argillaceous mass. At the mountain ledge of the Námarféyall, and at Krísuvik, this gypsum is found to penetrate the argillaceous masses in *connected strata* and *floor-like* deposits, which not unfrequently project as small rocks where the lower soil has been carried away by the action of the water. These deposits are sometimes sparry, corresponding in their exterior very perfectly with the strata of gypsum so frequently met with in the marl and clay formations of the *Trias*."

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* Dr. Murray informs me that this Arragonite is found in a little bay within six miles of Scarborough, in the seams and crevices of the upper calcareous grit. He describes it as fibrous, compact, or imperfectly mammillated, wanting the oblique cleavage of calcite, scratching Iceland spar, and flying into powder in the flame of a taper. Mr. Procter having at my request taken the specific gravity of a fibrous specimen, finds it 3, and confirms Dr. Murray's description of the other characters of this mineral.

† The only peculiarity is that a basaltic dike traverses the district at a distance of a few miles from the site of the fossils.

‡ The Lias fossils sometimes also contain *galena*. Blum describes a bivalve from a ferruginous oolitic rock near Semur, the shells of which consist entirely of crystalline laminæ of *specular iron*; and a cardinia from the lower lias, according to Bischof, likewise consists of the same mineral, which we know elsewhere as a result of volcanic action.

The great disturbances and fractures, the trappean rocks, and the fragments of porphyritic conglomerates, at the bases of these formations, tend to confirm the opinion of Bunsen, that they have had a metamorphic origin, an origin very probably common to other beds, whether consisting of marl, shale, or sand. All the sand-beds now forming are due to the disintegration and detritus of ancient sandstones, a process, which continued through a great lapse of time, has but coated some portions of the sea-side with unconsolidated sand. In the soundings of the Atlantic depths, the microscope, according to Maury, has failed to detect a single particle of sand or gravel. For the origin and consolidation of the inferior grits and shales we must look to actions, mechanical and chemical, more potent than those which the present tranquil course of nature presents. In examining the carboniferous sandstones of the Blue Mountains in New South Wales, with their shales and coal-beds, more than 12,000 feet in thickness, Darwin was "surprised at observing, that though they were evidently of mechanical origin, all the grains of quartz in some specimens were so perfectly crystallized that they evidently had not in their present form been aggregated in a preceding rock;" and he quotes Wm. Smith as having long since made the same remark on the millstone grit of England. If any one, in fact, will observe with a lens the surfaces of the quartz pebbles included in that grit, he will find on most of them numerous *unabraded facets*, which bear evidence of a quartz-crystalline action having pervaded the rock whilst its consolidation was going on.

There can be no better proof of widely-spread chemical action due to heat than the frequent presence of *crystallized silica* in every part of the stratified rocks.

The deeper we descend in the strata, the more plentiful are the veins and beds of *quartz*, and the more manifest the signs of *metamorphic* action. Von Buch was the first to explain, on the principle of metamorphism, the change of calcareous rocks, in contact with pyroxenic porphyries, into dolomites; and in 1835 the same principle was extended by Fournet to the *metallization* of rocks by contact with quartziferous porphyries, and to their *felspathication* and *silicification* by the contact of granite. "Since the theory of a central fire," he observed, "has been confirmed by modern researches, all the great questions in the history of the globe appear susceptible of a simple solution, and it is astonishing that chemists have not yet carried their views in this direction. From the moment that we consider the terrestrial globe as a mass of which the different parts have successively undergone the action of fire, we must also conceive, as a necessary consequence, a series of chemical phenomena, such as calcination, fusion, *cementation*, &c.," meaning by this latter term, the mutual molecular interpenetration of bodies in *contiguity*, a process of which I shall presently have to offer a remarkable example.

There was one mineralogical chemist, however, of high eminence, who had long before carried his views in the direction desired by Fournet. In 1823, Mitscherlich, having examined the forms, and analysed the ingredients, of forty crystalline products of furnaces[*], to which Berthier had contributed several parallel results of experimental processes, pronounced them identical with various native minerals, and in particular with peridot, pyroxene, and mica. In the artificial mica, however, he found *lime*, of which granitic mica scarcely contains a trace; and this led him to speculate on the cause of the chief chemical distinction between the granite and trap formations, consisting in the absence of calcareous and magnesian silicates from the former. Supposing, he argued, that the primary rocks were formed at that stage of the earth's refrigeration when $\frac{3}{4}$ths of its water were in a state of vapour, the pressure on every part of its surface, computed according to Laplace's calculation of the mean depth of the sea, would be 225 atmospheres[†]; but under such a weight the affinity of lime for silica would cease; hence the crystals of uncombined silica in Carrara marble.

The surmise has since been brought into evidence by an experiment of Petzholdt, in which pulverized quartz, heated to whiteness with an equal weight of carbonate of lime in an *open* vessel, was found to form a silicate with the lime, but produced no combination when heated in a strong, *close* vessel of iron.

The crystallization of the primary rocks was supposed by the early Plutonic theorists to be due to *slow cooling*; but this principle alone does not satisfy the phenomena. The crystalline structure of granite is seen, for example in Glen Tilt, at Shap Fell[‡], and elsewhere, to be equally uniform in its partial irruptions into the superior strata, as where it appears to be the foundation stone of the earth's crust; it has crystallized in its accustomed manner, where it has penetrated fissures of the upper beds in plates as thin as the leaves of a book and threads as fine as a hair, and even where it is involved in the invaded *stratum* so that no junction with any vein can be observed. How could it have been thus injected in a state of fusion, unless of the most liquid kind? and how could the heat of such liquidity, in a material of which the fusing-point is so high, be otherwise than *rapidly* cooled down?

Furthermore, the quartz which forms so large a constituent of granite, has always the specific gravity of *crystalline* silica, which exceeds that of any other species of silica. But Deville and others have shown that *fusion*

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[*] Annales de Chimie, tom. xxiv. p. 258, 1824. Mitscherlich sur la production artificielle des minéraux crystallisés—"j'ai trouvé, à Fahlun, du silicate et bisilicate de protoxide de fer, à Garpenberg, du mica et du pyroxene, les mêmes figures crystallines, et tous les autres caractères des minéraux correspondans, le bisilicate de protoxide de fer et de chaux, de magnésie et de chaux, les trisilicates de chaux, de chaux et de manganèse, le fer oxidé (ferrosoferricum), le protoxide de cuivre, le deutoxide de cuivre, l'oxide de zinc, les sulfures de fer, de zinc, de plomb, l'arsénieure de nickel, &c. &c., et beaucoup d'autres substances en cristaux bien prononcées.

[†] In Mitscherlich's Mémoire, as printed in the 'Annales de Chimie et de Physique,' tome xxiv. pp. 372, 373, the atmospheres are stated as 2250, deduced from a mean depth of sea, 96,000 feet, with a cipher too much, that is, in both cases.

[‡] I understand from Mr. Marshall that the ramified granite of Shap Fell is similarly crystallized with the rest of the rock, but finer grained.

lowers this specific gravity to a constant amount, and that *fused* silica does not recover its density in cooling. Crystalline granite, as Delesse has shown, passes by fusion from the density of 2·62 to that of 2·32, and Egyptian porphyry from 2·76 to 2·48.

Again, the felspar in granite is encrusted by the quartz, the most fusible by the least fusible material, contrary to all experience of crystallization either from solution or fusion.

Lastly, all the *minerals* of which granite is composed have been artificially produced, and their production has in every instance taken place at temperatures far below that of the fusing-point of that rock. The first specimens of artificial felspar analysed by Karsten, and measured by Mitscherlich, were found in the lining of a copper furnace amongst a sublimate of zinc. Mitscherlich tried to obtain the like by fusing several pounds of native felspar in a porcelain furnace, and subjecting the mass to a process of slow cooling, but without success*. In the Mulden smelting works, Cotta observed the walls of the furnace traversed, in the joints of its masonry, and in the cracks which it had undergone, by beautiful metallic veins, the sides exhibiting the phenomena of impregnation and alteration as in the boundary walls of natural veins, and the ores consisting of galena, blende, iron and copper pyrites, purple copper, Fahl ore, native copper, &c. In like manner pyromorphite ($\dot{\mathrm{Pb}}^3\,\overset{\cdot\cdot\cdot\cdot\cdot}{\bar{\mathrm{P}}} + \frac{1}{3}\,\mathrm{Pb\,Cl}$), in well-formed six-sided prisms from the iron furnace at Asbach, was found attached to the stones of the masonry. There can be no doubt but that Karsten's crystals of felspar, like these, were formed by gaseous sublimation; and an analogous process would account for the felspar observed by Haidinger in a basaltic cavity, under the form of Laumonite, and by Bischof in a porphyritic bed, in which a Trilobite also was found.

A new view of the production of minerals has been opened by Ebelmen, who obtained the most refractory crystals of the granitic rocks, such as spinel, emerald, cymophane, and corundum, by *segregation* in the interior of a fused mass. They were formed at a heat far below that which would fuse either those crystals or granite, by means of the evaporation of a fusible and volatile medium. Gaudin also, on the same principle using a similar alkaline solvent, and substituting sulphuric for boracic and carbonic acids as the volatile ingredient, obtained the ruby.

To the same category may be referred an experiment by Precht, who having added to a transparently fused frit, weighing 1½ cwt., a considerable quantity of felspar, found, after cooling, that a large portion of this mineral had separated itself in foliated masses, and in several distinct crystals.

The most important light, however, on this subject, especially in relation to metamorphic phenomena, is from the experiments of Daubrée on the reaction of *gaseous* compounds upon various earthy bases. Conveying the chlorides of tin and titanium over lime at heats varying from 572° to 1652° Fahr., he produced crystals of tinstone and brookite; by variations of the same principle, at heats not exceeding redness, he obtained all the following minerals:—wollastonite, staurolite, peridote, disthene, willemite, idocrase, garnet, phenakite, emerald, euclase, corundum, zircon, periclase, spinel, augite, diopside, gahnite, franklinite, hæmatite, felspar, and tourmaline in hexagonal prisms imbedded within crystals of *quartz*. The process was of this description:—Chloride of *aluminium*, passed over lime at a red heat, produced corundum; chloride of *silicium*, passed in like manner over seven equivalents of potash or soda and one of alumina, produced the different species of felspar: the latter named gas, decomposed by lime at the same heat, or by magnesia, alumina, or glucina, gave *crystallized quartz* in the usual form of the pyramidal hexagon, passing below into a silicate of the associated bases. "The most remarkable part," as Daubrée has remarked, "connected with these reactions, in a chemical, and especially a geological point of view, is that the silicium and the silicates thus produced have an extreme tendency to *crystallize*, and that the crystallization takes place at a temperature far below their points of fusion." "The manner," he adds, "in which quartz and the silicates are connected with the granite rocks has long been a difficulty in all the hypotheses on the formation of the rocks called primitive. Now we find, in our experiments, that *quartz* crystallizes at the same time with, or even later than, the silicates at a temperature scarcely exceeding a *cherry-red* heat, and consequently infinitely below its point of fusion."

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* Mr. Marshall fused a large mass of granite, and cooling it slowly obtained no crystals.

M. Daubrée disclaims the supposition that those rocks themselves were formed after the formula of his experiments. Nevertheless, considering the probability that formations at higher temperatures, now obliterated, may have preceded that of the granitic rocks, observing the uniform crystallization of granite in the tenuity of its ramifications, as well as in mass, and perceiving that Daubrée by his process has reproduced almost all the granitic minerals, and among them not only the felspar, but the *crystalline quartz* of granite,—it must be admitted that such a theory is worth attention.

Durocher has added to Daubrée's researches two capital experiments, of direct geological application, in obtaining the sulphides of the mineral veins by the reaction of sulphuretted hydrogen on the chlorides of the metals in a state of vapour, and in having effected the metamorphism of limestone into dolomite in an atmosphere of the vapour of chloride of magnesium.

A theory of sublimation, however, may admit of many modifications, and may be combined with the principle of segregation illustrated in the experiments of Ebelmen. Deville and Caron, having fused bone phosphate at a red heat in excess of chloride and fluoride of calcium, found that lime apatite crystallized out in cooling, and was easily separated by washing from the soluble salts. In like manner, with different bases and different chlorides, they obtained the numerous varieties of apatite and wagnerite. And they observed further, that all these minerals became *volatile* at a slightly elevated temperature in the *vapour* of the chloride amidst which they were formed.

Senarmont, pursuing another course, had applied a heat somewhat exceeding 662° Fahr. to an aqueous solution of hydrochlorate of alumina, confined in a close tube, and thus decomposing it into its volatile and solid ingredients, obtained *corundum*, distinctly crystallized and mixed with *diaspore*, the same substance under a different form, and with different chemical properties, thus repeating in a remarkable manner that process by which the same minerals are found in nature similarly intermingled. He also succeeded in eliminating crystals of quartz from hydrate of silica by dissolving the hydrate in water charged with carbonic acid, and gradually raising the temperature of the tube which contained it to a heat of from 400° to 500° Fahr., and by analogous methods he obtained carbonates and sulphides identical with native minerals. In some of these experiments the process was so varied as to show that the separation of the anhydrous crystals was due to the gradual withdrawal of the dissolving gas. The hydrated sesquioxide of iron, also heated in water of the temperature of 360° Fahr., was dehydrated, becoming magnetic. In an experiment by Wöhler, on the contrary, apophyllite dissolved in water at the same temperature, returned on cooling to its original form, retaining its water of crystallization. To this class of discovery Daubrée has likewise added some valuable facts, having obtained regular crystals of quartz, by decomposing, with the vapour of water alone, the interior of a glass tube subjected to a low red heat; at the same time silicates were formed, hydrated or anhydrous, according to the degree of heat; when fragments of obsidian were inserted, crystals of Rhyacolite appeared; and the silicated water of Plombière being substituted for plain water, and kaolin for obsidian, crystals of diopside insinuated themselves into the silicated substance of the tube, and the kaolin was changed into a substance possessing felspathic characters.

All these experiments are adverse to the idea that the primary rocks have undergone fusion. The best natural criterion, perhaps, of the *temperature* at which they were formed, was afforded by the discovery, in 1828, of a method of manufacturing *ultramarine*, based on Vauquelin's identification of a furnace-product with the Lapis lazuli found in granite and in primitive limestone. In some specimens which I possess of the latter rock, this beautiful mineral may be seen enamelling with minute specks, and with perfect distinctness, within and without, all the plates of the calcareous crystals, which are here and there interspersed with small crystals of sulphate of lime. The heat at which the artificial ultramarine is made is that of *redness*. A lower temperature will not suffice to produce the colour, and a higher destroys it.

We can now better understand how Hunterite, a white felspathic mineral containing 11·6 per cent. of water, can have been formed where it is found; a *hydrated* silicate of alumina in the bosom of *molten granite* is an anomaly for which high pressure would scarcely account; but if the rock was at the temperature only of a low red heat, the formation of this mineral, and of the hydrated micas, will no longer appear a marvel.

Other notices of ancient degrees of heat have been observed in the strata. In a cavity within a quartz crystal from Dauphiné, Davy found a viscous inflammable fluid in small quantity, in a perfect *vacuum**. In the cavities of other quartz crystals he found water and rarefied air. Sorby, having determined the amount of rarefaction in one such from a bed of mica-slate, in which he detected many others, calculated the temperature of the crystal at the time of its formation to have been 320° Fahr. In one case Davy found evidence of *pressure* which had condensed the elastic fluid in a crystal of quartz, and Brewster observed the like in crystals of topaz.

From a general review of the researches now detailed, the following inferences may be drawn:—

1. That all the consolidated strata, viewed chemically, bear marks of subjection to an action of heat agreeable to the theory of the earth's refrigeration, in direct proportion to the age of their deposit; and that they show that action most explicitly in the presence, throughout, but more abundantly as the series descends, of that peculiar form of silica which is chemically reproduced by the action of heated volatile matter.

2. That the igneous minerals were formed by molecular aggregation, at a heat not exceeding, perhaps, that of an ordinary fire, either as a residuum from the expiration of fusible and volatile materials, or more generally as a deposit from volatile forms of matter.

As there are two classes of eruptive rocks, the *quartzose* and *unquartzose*, so there are two classes of *emanation* which accompany them, and deposit *earthy minerals*, differing for each class, in the neighbouring strata. They generally mantle round the rock, and but seldom penetrate it; as if it had rather made room for them to rise, than as if they made part of its substance. Yet they bear a resemblance to the character of the rock which they follow. Thus the *crystallized oxide of silicon* is the characteristic ingredient of granite rocks; and the earthy minerals imbedded in the metamorphic strata around such rocks resemble quartz in being *simple crystallized oxides*,—innumerable gems, for instance, of the *crystallized oxide of alumina*—vast masses of the same, many tons in weight, in the form of emery, encysted in limestone which has been metamorphosed by rocks of granitic character,—still greater masses of *crystalline sesquioxide of iron* in similar relation to those rocks,—*crystalline peroxide of tin* shot through them into the strata above.

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* Rose quartz from granite, and cornelian from trap, are coloured by a carburet of hydrogen; crystals of graphite also have been found in quartz; but as carbonic acid must have existed before plants could grow, these facts are no proofs of antecedent organic structure.

In the eruptive rocks which followed the *quartzose*, these minerals, with almost all the quartz, died out, and were succeeded by others of a more *complex* nature appropriate to the porphyritic, trachytic, basaltic, and lavic eruptions. Yet all these, as well as the granitic, are attended by *similar metalliferous veins*, which grow very weak in the latest, but still show, at least as far as the eruption of the more ancient lavas[*], a continued communication with a common reservoir deeper seated than any of them.

Davy saw the lava of Vesuvius issuing, as if forced up by elastic fluids, perfectly liquid, and nearly white-hot, its surface in violent agitation, with large bubbles rising from it, which emitted clouds of white smoke, consisting of common salt in great excess, much chloride of iron, and some sulphate of lime, accompanied with aqueous vapour, and with hydrochloric and sulphurous acids. It contains also realgar and sulphide of copper, due probably to the reaction of sulphuretted hydrogen on the chloride of the metal.

In the early time of these eruptive emanations, when they escaped at many points with little interruption, the land rose only to low levels above the waters. As the crust of the earth grew more solid and weighty, and the vent was confined to fewer lines of shrinkage, the elastic elements of disturbance upheaved the incumbent beds with greater power, and the mountain chains culminated to their utmost height. In the progress of refrigeration the compressing and imprisoned forces became nearly balanced, and the residual predominance of the latter produces the phenomena of existing earthquakes and volcanoes.

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[*] Though the presence of quartz in lava has been denied, the following account of its coexistence with schorl in that of the valley of Maria in Lipari by Spallanzani shows that it does exist in ancient, perhaps basaltic, lavas, and strikingly illustrates the theory of its sublimation, as here advanced. "Among the lavas partly decomposed we find pumices and enamels containing felspars and scales of black schorls, and certain curious and beautiful objects, which derive their origin, in my opinion, from filtration. The lava is white and friable to a certain depth, of a petrosiliceous base, full of small cells and cavities, within which these objects make their appearance:—First, minute crystals of schorl; from the inside of these cells project very slender schorls, sometimes resembling minute chestnut bristles, sometimes a bunch, a plume, or a fan, to be ascribed to filtration after the hardening of the lava, since though it is common to find schorls in lavas, they are found incorporated within them, not *detached* as in this case. The second filtration has produced small *quartzose* crystals, and the manner of their distribution in prodigious numbers renders them a very singular phenomenon among volcanic objects. Wherever the lava is scabrous, wherever it has folds, sinuosities, cavities, or fissures, it is full of these crystallizations. The larger crystals extend to 3½ lines, the greater part about ½ a line. They consist of a hexagonal prism, infixed by the base into the lava, and terminated by a similar pyramid. Three crystals, among those I examined, were terminated by two pyramids, the prism being attached to the lava by a few points, and the prisms projecting out. The most regular are in small cavities, but not a few are on the surface of the lava. The lava, embellished with these, forms immense rocks and vast elevations hanging over the sea, which, whenever they are broken to a certain depth, are found to contain these crystals, with capillary schorls, not very numerous. I have in my possession a group of needle-formed crystals from Mont St. Gothard, within which are seven small prisms of black striated schorl. The same may be observed in these minute crystals. *One of these was perforated from side to side by a needle of schorl, the two ends of which projected out.* The formation of these capillary schorls must have preceded that of the quartzose crystals; otherwise it is impossible to conceive how the former should have penetrated the substance of the latter. In remelting the lava in a furnace, the quartz crystals remained perfectly unaltered."

Spallanzani also states, that in this lava are garnets and chrysolites more refractory in the fire than the matrix; and he adds that since Dolomieu's visit to the adjoining *stoves*, when the whole ground on which they stood was saturated with hot vapours issuing everywhere from small openings an inch or two in diameter, at the time of his own visit these were reduced to one, exhaling some sulphur and encrusted with soft pyrites.

In the earlier periods, unmutilated skeletons, undisplaced scales, entire ink-bags, and florescent fronds, indicate conditions of nature which would now be called unnatural, a history of sudden death and speedy embalment, common, not to individuals only, but to generations and species. The preservation, in exquisite casts, of the most delicate organizations indicates a speedy but a tranquil entombment, which it would be difficult to refer to any other agency than that of gaseous emanation through the waters in which the plants and animals existed. Alcyonia and sponges, looking like recent specimens preserved in the places where they grew, point to a process of silicification, chiefly anhydrous, which anticipated decomposition. In the decreasing activity of internal heat and insalubrious emanations, we see the advancement of the physical and chemical conditions essential or advantageous to *life*; and with the progress of such conditions, favourable to the development of higher and higher forms of organization, we find a perfect correspondence in the natural history of organized fossils, and the increasing tones of the "Diapason, closing full in Man."

From the theory of heat and the facts of geology, combined with physiological considerations, we learn that there was a *definite* era, in which the earth first became capable of supporting vegetable and animal life; and we may account for the late appearance of man, by observing that there were no conditions adapted to the well-being and progress of human nature, till this state of things had yielded to a healthy atmosphere, a moderate heat, differentiated zones of life, stable forces, and a stationary standing ground.

In the rudimental ages of the earth we behold an ever-changing scene of new and fitful conditions passing in rapid succession. Through all the stages of its existence previous to the present uniformity, so favourable to the exercise of reason and the freedom of will and action, we see force gradually subsiding, and the time allowed to life expanded into a wider liberality. Our ideas of its duration, as compared with indefinite ages, are equally limited with our view of its magnitude, in comparison with space or matter; we can find in geological data no chronology but that of *priority*; the fossil records even of its unconsolidated beds have not yet supplied us with the key of the *cypher* which should connect geology with human history. If ever we come to know the age of the primary rocks, or of the protozoic strata, it can only be by combining physical data with the experimental reproduction of granite, and a knowledge of the heat which the lowest organisms can bear, and live.

Since Hall first applied chemistry to the service of geology, few attempts have been made in this country to pursue the path which he opened. In 1833 the British Association entrusted to a commission, consisting of Prof. Sedgwick, Dr Daubeny, the late Dr. Turner, and myself, the task of illustrating geological phenomena by experiments which it was hoped might have thrown light on some of the subjects discussed in this Report. Disappointed of the greater part of the fruit of these experiments, I yet believe that the few results which I now lay on the table of the Section will not prove devoid of interest, especially as evidence of the low temperature at which bodies scarcely reputed volatile are capable of being sublimed.

The iron furnaces of Yorkshire having been selected as furnishing the best field for these experiments, it fell to my lot to conduct them. Every facility was afforded me by the zeal and liberality of the proprietors and managers of two furnaces, one of which at Elsicar, belonging to the late Earl Fitzwilliam, and managed by Mr. H. Hartop, worked for a period of five years; the other at Low Moor, belonging to Messrs. Wickham and Hardy, prolonged its unintermitting blast for fifteen years. The materials for the experiments, in addition to those which I was myself able to supply, were provided partly by a grant from the Association, partly by an extensive donation of minerals and fossils from the stores of the Yorkshire Philosophical Society. Professor Phillips also, who was then in charge of that Society's Museum, lent me his valuable assistance.

The object kept in view, in devising experiments of so long a duration, was to subject the greatest possible variety of materials to the greatest possible variety of conditions, such as it might be presumed had formed, or altered, rocks, minerals, and mineralized organic remains.

These were arranged in numerous crucibles, upright and inverted, and within two strong tripartite boxes of deal bound with iron thongs; one of these was stored with large blocks and copious powders of granite, basalt, limestone, grit, and shale, with whole and pounded minerals of every kind, hydrates and anhydrates, the ingredients of a great variety of minerals compounded in proper proportions, all the different salts and elements calculated to react upon them, with almost every metal adapted to form veins or to register heat; the other contained organic substances, fossil and recent plants, shells, corals, reptiles, and bones, disposed in clay, sand, chalk, marble, gypsum, fluor, sulphates, muriates and other salts of soda and potash which might disengage volatile elements by their mutual action, to react on fixed constituents.

At the Elsicar furnace I was allowed, whilst it was being built, to insert crucibles in the back of the masonry in immediate contiguity with the body of melted iron. At Low Moor it was agreed to place boxes filled with crucibles and materials under the bottom stone, before the furnace was built. This stone, consisting of millstone grit, 15 inches thick, though it gradually wears hollow in the centre, retains the iron fused upon it usually for fourteen or fifteen years, without being materially impaired. In its crevices are often found the beautiful cubic crystals of nitrocyanide of titanium, first brought into notice by Dr. Buckland.

In this situation the temperature to which the contents of the boxes would be exposed could not be exactly foreseen. It was presumed that in the centre it would be near to the melting-point of cast iron. It will be seen by reference to Plates IV. and V., which give a section and plan of the furnace, that the boxes did not occupy the whole space beneath the bottom stone. It occurred to me therefore, when these had been placed in position on a bed of sand, covered with the same material, and built up with fire brick, to deposit round them in a similar bed of sand, and enclose in like manner within walls of brick, lumps of various metals, and of granite, sandstone, fossiliferous shale, and limestone. From these supplementary experiments are derived the most interesting of the results which I have to describe.

For when at the expiration of fifteen years the furnace was blown out, I found nothing left of the boxes but the iron straps with which they were bound, in a state of oxidation; a few crucibles and portions of crucibles only had survived the general wreck of their contents; granites, basalts, limestone, choice minerals, measured pieces, weighed powders and compositions, had disappeared; all the exactness with which Professor Phillips had arranged for identifying the altered substances by their position and by comparison with reserved specimens, was lost labour.

Nor did I find the deposits in the Elsicar furnace, at the end of five years, to have fared any better. From all these carefully devised experiments I can produce but two worthy of notice. One of them exhibits the conversion of river sand into sandstone, with a vacuity in its axis left by the volatilization of a recent plant. The stone has considerable tenacity, and came out of the crucible, with no adhesion to its sides, a perfect cast; no salt had been added to it, nor is any separable from it by boiling. The close cohesion of the grains of sand by the action of heat may have been facilitated by the intermixture of some impurities, referable to oxide of iron, and possibly to felspar. The only vestige of the plant is a skin of silica on the surface of the place which it occupied in the interior of the sand, coating the vacancy, but not furnishing an impression from which the character of the plant can be recovered. The stone showed signs of splitting from shrinkage in an oblique, or nearly vertical direction, a tendency which might probably have been more conspicuous had the experiment been on a larger scale.

The other specimen is a translucent mineral of a pure *blue* colour. This colour it does not lose when heated red-hot in the outer flame of a candle. Melted into a bead with carbonate of soda, it passes into a pure opake white; the same also with a small proportion of borax; when the proportion of the borax is increased, the bead is transparent and colourless; dissolved in hydrochloric acid, the mineral loses its colour. The solution contains much sulphate of lime, and some silica and alumina, whether potash also, or soda, I have not determined; tested with prussiate of potash, it shows no trace of copper, and none, or scarcely any, of iron. This substance therefore belongs to the class of minerals of which Lapis lazuli and Haüyne are varieties. It has been formed irregularly under a thin crust of sand to which it adheres, is imbedded in sulphate, sulphide, and carbonate of lime, and accompanied with crystallized fluoride of lime. Whether this fluoride is a recomposition, or part only of the original mixture from which the blue mineral has been derived, I cannot say. The crucible certainly contained pounded fluor, and a sulphate, which underwent decomposition, and partially decomposed the fluoric crystals.

But the objects to which I have alluded as possessing a new and unexpected interest, are the metals above mentioned as having been supplementarily placed, outside the boxes, under the bottom stone of the Low Moor furnace. The specimens consisted, originally, of pieces, of which chromographic plates have been appended to this Report, cut from a bar of *zinc*, a block of *tin*, a pig of *lead*, and a plate of *tile-copper*. They occupied, severally, the places marked in the accompanying ground plan of the furnace, 1, 2, 3, 4, as numbered at the time of the deposit. It will be seen that none of these pieces have undergone fusion, that of which the melting-point is lowest (the block tin) preserving perfectly its dimensions, the exact shape into which it was cut, and the sharp edges of the cutting. The external coat of the *tin*, to the depth of from $\frac{1}{8}$th to $\frac{1}{6}$th of an inch, is converted into deutoxide, crystalline, transparent, and of the same specific gravity as the native ore; between this and the metal, intervenes in some parts a space, which, with the striation of the metallic surface, indicates that a portion of the substance has been dissipated.

Of the *bar-zinc*, more than half has been changed, though it preserves its original form, into a mass of crystalline oxide, interspersed with globules of the metal, burrowed in all directions with *drusy* cells and cavities, and showing extensive sublimation into the indurated sand which envelopes it. The nature of the sublimation is manifested by a number of prismatic spicula of *metallic* zinc, about $\frac{1}{8}$th of an inch long, standing within the cavities.

But that which is chiefly remarkable is the *tile-copper*, in respect both to the temperature at which it has been volatilized, and the combination and interpenetration which its molecules, in a volatile state, have effected with its nearest neighbour, the *lead*. I have caused a drawing to be made of these specimens in their relative positions, as they lay in proximity to, but not touching, each other, having a portion of sand interposed.

It will be seen that a very considerable portion of the copper plate has been dissipated, that the surface has been *sweated* down, and in some parts the whole substance has evaporated away. Bright crystals of red oxide of copper line the wasted surface, which is also covered above with a coat, $\frac{1}{8}$th of an inch thick, of mixed crystalline oxides of copper and lead; and in the hollow which the dissipation of the metal has left between it and the indurated sand, is a sublimate consisting of fine twisted coherent threads of metallic copper, like those met with in mines and slags. Where nearest to the lead, it has so intermixed its exhalations with those proceeding from that metal as to have spread over the upper leaden surface a coating of green crystals, consisting of a double oxide of copper and lead. Beneath, and round the lead, at its contact with the sand (which below has penetrated its substance without altering its form), runs a pink skin, marking the path of the red oxide of copper. I cut the lump of lead in half, and found it not only traversed in the middle by a seam of mixed oxide, but, what was still more remarkable, dotted with spots of metallic copper, which had found their way to the very centre of the mass, and even reached the opposite side.

That it was the *metal* in this case, as in that of the zinc, which became volatile, and was subsequently deposited in the form of specks and filaments of copper in some places, and combining with oxygen, as a crystallized oxide in others, cannot be doubted. To attribute these effects to *thermal electricity* would not be consistent with the facts; for there was here no contact, and no circuit. The penetration of the lead by the molecules of copper may be called *Cementation*, and be supposed to be due to capillary attraction of pores distended by heat acting on the volatile particles.

But the surprising part of the result is, that the sublimation of copper by heat should have taken place at so *low a temperature*. These four metals, in close proximity, and all acted upon in the same manner, were their own mutual thermometers. It was impossible that the heat to which the copper plate, as a whole, had been subject could have been higher than the melting-point of the unfused lead and tin. I can attribute this unexpected fact to no other cause than the continual and protracted passage of hot currents of air and vapour, mingled perhaps with carbonaceous gas from the neighbouring wooden boxes*; and it seems probable that if the central portion of the bottom stone had withstood to the end the action of the furnace, or if the buried boxes had been protected with a vault of brick, more light might have been thrown on the transfer of molecules at moderate temperatures by similar effects produced on other materials.

I owe an apology for having delayed this Report much longer than I should have done, had the bulk of the experiments been attended with better success. I have been reminded of them by the design of a member of the Association to institute some of a similar character with the added conditions of pressure and steam. Whoever should now undertake such experiments would conduct them on the vantage ground of the later researches which I have here noticed, and might obtain results of high interest to geological and chemical science. It may be doubted whether heat protracted through many years, or even extraordinary pressure, may be essential elements of such results. The unintermitted presence of volatile materials, for a considerable time, passing over and dwelling among those of greater fixity at temperatures mounting up to a red heat, may be the only needful condition; and if a furnace were appropriated to this object, it is not difficult to conceive a construction and application of it which would fulfil such a requirement.

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* If I am right in believing that an oolitic Echinus, Pecten, and Coral, and an Ammonite from the Lias, which I recovered from the furnace, are those marked in the Plan with the Nos. 8, 9, 10, then, as these were reduced to alkalinity, though without change of form or markings, it would follow that the carbonic acid under the same circumstances separates from lime at an equally low temperature of the mass, under the partial action of hot currents.

If any one could succeed in effecting the synthesis of *pseudomorphic crystals*, or of *granites and porphyries*, he would certainly perform a great service to chemical geology. In the first of these subjects of experiment success is scarcely to be looked for, except in the metamorphic action of heated volatile agents. It is possible that granite also, and porphyry, might be formed by a process of volatilization; or they might perhaps be produced as a residual igneous crystallization out of a mass, of which the flux had been removed from the denser substances by sublimation, solution, or pressure.

It should appear that the production of *marble* is also a problem still undetermined. Rose has expressed an opinion, founded on his own experiments, that the solid substance which Sir J. Hall obtained, by igniting chalk under a pressure that prevented the extrication of the carbonic gas, cannot have been *marble*. Possibly the presence of an excess of the acid may be an additional requisite to the production of a perfect specimen.

Since this Report was drawn up, I have seen a memoir by M. Daubrée* which contains a very able and complete exposition of the progress of geological chemistry. His observations on the deposit of zeolitic crystals and other minerals discovered in the interstices of the old Roman brickwork and concrete at Plombières†, which have undergone the action of silicated waters springing from the earth at a temperature not, now at least, exceeding 158° F., seem to have solved the problem of the deposit of such crystals and minerals in the vesicles of basaltic rocks, and to have proved them to be due to aqueous infiltration whilst the rock was still hot.

His views on the formation of another class of minerals, and the origin of the granitic and other early rocks, seem to be not equally satisfactory. To these he has been led by his own late experiments on the effect of aqueous vapour in decomposing obsidian and glass. He propounds, with the diffidence, however, which belongs to a hypothetical speculation, a theory to the following effect—that in a primæval state of the earth, when the heat now known to exist in its interior extended to the surface, as that surface cooled down to a certain point, the red-hot obsidian, or silicated glass, of its first coat was decomposed by water condensed from a state of vapour, under great pressure, at a red heat; thus the quartziferous rocks were formed, at first as a plastic sponge, and when the water had evaporated as granite, the schist and slates immediately superincumbent upon it being the residuary product of the *mother*-waters.

But this speculation is open to grave objections. What principle of solidification, it may be asked, capable of *compacting* granite, is included in a process of *disintegration*? What has become of the *silicates* involved in it, to which we might look for such solidification, but which are absent from granite? The *mother*-waters which it supposes are incapable of diffusing the peculiar minerals encysted in the proximity of granitic rocks even to the distance of thousands of feet. No less unaccountable would be the absence of all the *zeolitic* and *opaline* substances that might have been expected. Everything tends to show that whatever the power of this process may be, it must be confined, at least, to the lavas, basalts, and trachytes.

That heated water has been so universal a solvent as M. Daubrée supposes, is rendered very improbable by a circumstance noticed by Cagniard de Latour in his celebrated experiments on vapour highly heated and compressed. In one of these, the addition of a crystal or two of chlorate of potash to water at the temperature of 648° F., proved sufficient to prevent any action of the aqueous vapour on the glass; so easily was it saturated by the presence of a more soluble material.

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* Etudes et expériences synthétiques sur le métamorphisme et sur la formation des roches crystallines, 1860.

† The presence of fluorine in the apophyllite of Plombières is remarkable, the more because Vauquelin analysed the waters with the express object of detecting this constituent, and denied its supposed existence in them.

Neither is it at all probable that any stratum which can be supposed to have preceded granite under extraordinary conditions of heat and pressure, can have resembled in any degree obsidian or glass. M. Daubrée takes the vapour expansion of the ocean over the globe as equivalent to a pressure of 250 atmospheres, somewhat exceeding Mitscherlich's supposition before quoted. On this pressure Mitscherlich, as has been said, sagaciously remarked, that it would probably materially modify the chemical *affinities* of bodies, and prevent the formation of *silicate of lime*. His anticipation has been experimentally verified; and an equally remarkable instance of the same principle has been lately observed by Mr. Gore, who has found, on immersing some fifty substances in *carbonic acid liquefied by pressure*, that in that state it is chemically inert, to such a degree as not to dissolve oxygen salts. In these cases it should seem that pressure favours *homogeneous*, or *simple*, at the expense of *heterogeneous*, or *complex*, attractions; and there is all the less reason for admitting M. Daubrée's supposition, that obsidian, or any vitreous silicates, preceded the granitic rocks.

We may carry these ideas further; we may extend our speculations from the heat and weight of a vaporized sea to the gaseous system of Laplace, and the ultimate atoms of Newton. Then, as the heat by degrees radiated into space, and as the repulsive force yielded to the forces of attraction, the first compounds would be of the *simplest order*,—water, and hydrochloric acid,—the chlorides of potassium, sodium, silicon, and aluminium, the oxides of magnesium and calcium, with others of a like class. Here we have both the materials of the sea, and of the primary crust of the earth; and at the same time all the power of consolidation which free crystalline force and enormous pressure can give to materials indisposed by that pressure to enter into complicated combination.

In contemplating the origin of granite, it is not, however, competent to us to regard it as a fundamental rock only, since it preserves the same crystalline character under various conditions of heat and pressure. But we must remember that the *gaseous* theory which we are imagining implies a residue, in an *internal gasometer*, of similar primary compounds confined in a highly heated, condensed, and elastic state at no great distance under our feet, from the sudden or gradual evolution of which it is not difficult to conceive that all the eruptive rocks and veins, and many of the phenomena of consolidation in the sedimentary strata, may be accounted for.

Every rock of eruption, and every mineral vein, which has shot up into the strata, indicates such an origin. The porphyries, trachytes, basalts, and lavas are essentially *chemical* and *crystalline* compounds. They differ from the quartziferous rocks only in this, that the chief part of the siliceous ingredients which characterize the latter having been antecedently used up, the greater fusibility of the former has more or less obliterated their crystalline structure.

In these speculations it matters not from what source we suppose the heat of the earth to have been derived. Perhaps, a law of gravity, together with the other forces of attraction, imposed on the ultimate particles of matter, may account for all the heat which is, or has been in the world. In any case, the most probable inductive conclusion from our knowledge of the earth's heat, and the phenomena of eruption, with the light thrown on the production of minerals by Daubrée's *first series* of experiments, and those of Durocher, appears to be, that mineral veins and eruptive rocks are the result of *gaseous combinations and reactions*. As regards mineral veins, this, I believe, is the opinion of most observers. But we see the same metamorphic effects which are produced by *them*, equally produced by the presence of *any eruptive rock.* If a stratum of limestone be invaded, and a portion of it included in the invading substance, that portion is not unfrequently impregnated with magnesia and converted into dolomite, equally by a mineral vein or a granitic rock.

The advantages which this theory possesses over any that have yet presented themselves, are that it accounts for all the following phenomena:—

1. The characteristic *structures* of granite, and of gneiss and mica-slate,—which may be compared to the deposits of graphite in gas-retorts, *solid* where the carburetted gas aggregates its decomposed molecules of carbon in confinement, but *foliated* and *quasi-stratified*, where the gas chances to escape through cracks in the retort into the more open chamber of brick-work;—

2. The *perfect uniformity* of *crystalline texture* in granite, whether deep or superficial, in thin veins or solid masses, showing that neither great pressure nor slow cooling have been essential conditions of its crystallization;—

3. The *wide diffusion of zones or atmospheres* round the eruptive, and especially the granitic rocks, of mineral substances, and metamorphic effects, a phenomenon which, together with that of the filling up of mineral veins from below, is not accounted for by any other theory;—

4. The metalliferous and quartziferous impregnations of the sedimentary strata.

If, with Cordier, we divide the eruptive rocks into the *quartzose* (which correspond to the granites and earliest porphyries); and the *unquartzose*, comprehending the *felspathic* (which correspond to the later porphyries and trachytes); with the *pyroxenic* (which correspond to the basalts and lavas); and if we consider all these as originating from *gases*, accompanied by *aqueous vapour*,—then the phenomena show the amount of such vapour present in the *quartzose* formations to have been almost infinitesimal, whilst that which attended some parts of the *pyroxenic* formations was considerable. As regards the *sedimentary* siliciferous rocks, they show, in the *semiopaline, semiquartzose* composition of the siliceous beds, the action of anhydrous gas, aided by aqueous vapour. Aqueous vapour acts on silicates only at a *heat* approaching redness, and *conveys* no silica. Chloride of silicon would *carry* silica, and would diffuse it at a much lower heat, since it boils at a temperature below 140° F.

Connected with the preceding speculations the following remarks may deserve attention. There is a singular resemblance of mineral and crystalline constitution between the *pyroxenic* rocks and *meteoric* stones,—a resemblance, in fact, so close as to indicate a *similar* mode of production out of the same materials. The late optico-chemical discoveries of Bunsen and Kirchhoff have shown, with a great degree of probability, that molecules of *iron*, *nickel*, and *magnesium* abound in the *solar* atmosphere; should the progress of those discoveries add *silicon* to this list, we have here again the chief materials, both of *meteorolites* and of *pyroxenic* rocks. In any case, whether we suppose the meteorite to have been contemporaneous with the earth, or to be ejected from the moon, or emitted from the sun, our thoughts are led back to a time when the whole solar system consisted of the same ultimate atoms, and are confirmed in the opinion that the meteorites and the fundamental rocks of the earth have undergone similar processes of molecular and crystalline combination, the *vitreous* coat of the meteorite, and the *vitreous* character of the later lavas, being due also to the same causes:—1st, to the fusibility of the material; 2ndly, to a more intense heat generated by a nearer proximity to an oxidating atmosphere; 3rdly, to a more rapid rate of cooling.

What our views, however, of the original constitution of matter may be, is a point of less consequence than what are the conclusions in geology to which we are conducted by observation and experiment. The general conclusions to be drawn from the foregoing researches seem to be these:—That no theory of the earth consists with the phenomena, which does not take into account a heat of the surface once amounting to redness;—that the most *prominent* chemical and crystalline compounds which laid the basement of the earth's crust, and continued to penetrate it, as far as into the tertiary strata, have disappeared in the *present eruptive system*;—that the nature, force, and progress of the past conditions of the earth cannot be measured by its existing conditions;—that to deduce accurate inferences in the sciences of observation, the attention requires to be directed less to general *analogies* than to specific and essential *distinctions*.

EXPLANATION OF PLATES.

PLATES IV. & V.

Section, and Plan, of the furnace in which the deposits lay for 15 years, the number of each deposit, external to the boxes, being marked on the plan.

PLATE VI.

Fig. 1 (Plan No. 4). Tile copper 5 in. × 2½ in. × ⅜ in. coated with laminæ of dark, red, crystallized oxide of copper, alternating with white and yellow crystallized protoxide of lead, and with a pink intermixture of crystallized oxides of copper and lead covered with sand indurated, but not vitrified, by protoxide of lead.

a. Twisted filaments of metallic copper. *b*. Crystals of red oxide.

bb. Laminæ of crystallized red oxide of copper alternating with protoxide of lead, and mixture of oxides of lead and copper.

c Particles of metallic copper. *cc*. Golden metalline spot.

Fig. 2 (Plan No. 3). Pig lead, 4½ in. × 3½ in. × 2½ in. View of upper surface, showing green and yellow double oxides of lead and copper, with spots of metallic copper.

d. Cavity from which lead has sublimed.

e. Spots of metallic copper.

f. Double oxides of lead and copper.

PLATE VII.

Fig. 3 (Plan No. 3). Pig lead, vertical section, showing exterior and interior seams of mixed oxides of lead and copper, green, yellow, and red, with spots of metallic copper.

g. Red oxide of copper between lead and indurated sand.

h. Spots of metallic copper in the interior of the lead.

i. Oxide of copper and lead. *kk*. Lead hardened by disseminated oxide.

Fig. 4 (Plan No. 4). Enlarged section of part of fig. 1, showing threads of metallic copper.

Fig. 5 (Plan No. 4). Part of fig. 1; enlarged view of pink mixture of crystallized oxides of copper and lead, with spots and threads of metallic copper.

PLATE VIII.

Fig. 6 (Plan No. 2). Block tin, 3 in. × 2 in. × 1 in., with a coat of transparent crystallized deutoxide from ⅛ in. to ¼ inch thick.

l. Striated surface of metal beneath oxide.

m. Crystals of deutoxide, transparent and colourless.

Fig. 7 (Plan No. 1). Zinc bar, in indurated sand, fractured, showing a surface partly metallic, partly crystalline.

n. Spiculæ of sublimed metal. *o*. Seam of metal.

Fig. 8 (Plan No. 1). Showing cavernous face of oxide of zinc with crystals of do.

p. Cupped hollows set with crystals of oxide of zinc, out of which globules of metal have sublimed.

Section of the Furnace

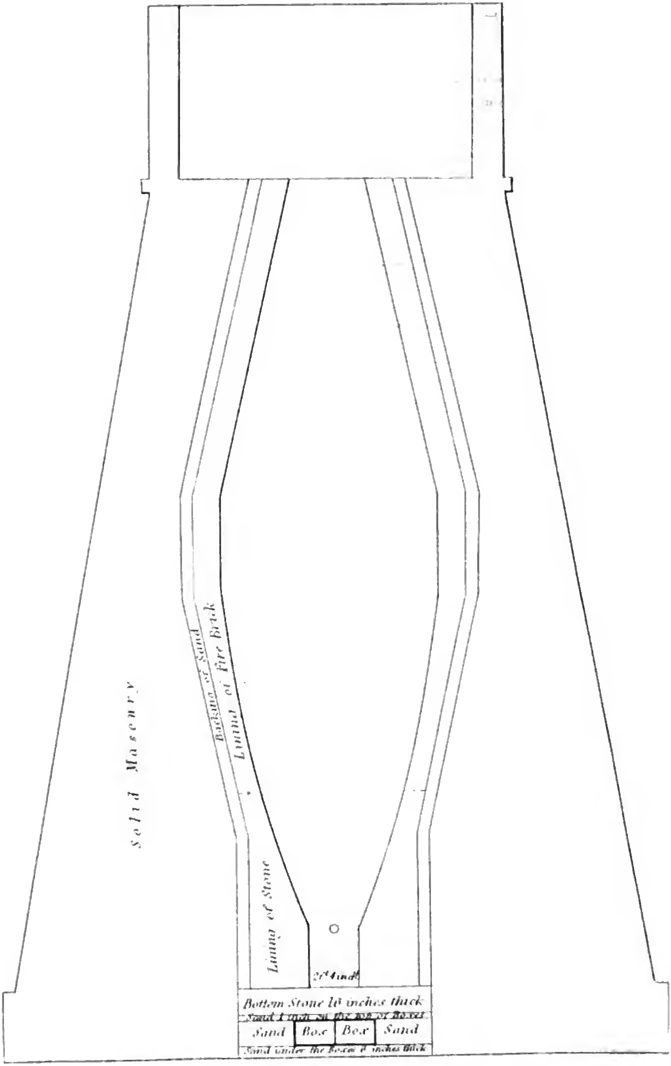
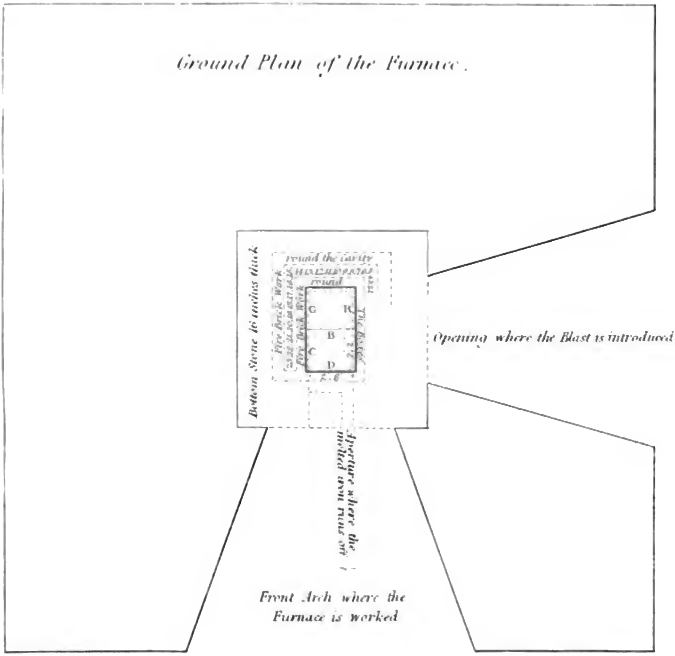

Solid Masonry
Backing of Sand
Lining of Fire Brick
Lining of Stone
2ft 4 inch
Bottom Stone 18 inches thick
Sand 1 inch on the top of Boxes
Sand
Box
Box
Sand
Sand under the Boxes 6 inches thick

Plate 5.

REFERENCES.

The melted Iron rests upon the bottom Stone in the space 2 feet 4 inches in the Section and the blast is introduced at the small Circle in Do. The figures from 1 to 23 on the Ground Plan represent the order and situation of the Deposits made in the cavity on the outside of the Boxes. The black lines in the centre of the Ground Plan represent the two Boxes whose two sides meet exactly in the centre of the Furnace. The letters G.R.B.C.D. agree with those marked on the Boxes.

Nº. 1. Zinc bar. } *See coloured plates 6 7 8*
2. Block Tin.
3. Pig Lead.
4. Tile Copper.
5. Pit Shale from Black Ironstone.
6. Black Ball Ironstone
7. Jet
8. Echinus in Malton Oolite.
9. Coral in Coral Rag.
10. Pecten in Malton Oolite.
11. Coral, recent
12. Chalk.
13. Nº. 11.395.
14. Whale Vertebræ.
15. Blue Limestone with Shells.
16. Magnesian Limestone.
17. Low Moor Pig Iron.
18. Septarium.
19. Flagstone.
20. Granite.
21. Ammonite in Lias.
22. Basalt.
23. Granite York Streets.



Ground Plan of the Furnace.

Bottom Stone 16 inches thick
round the cavity
round
Fire Brick Work
Fire Brick Work
G
R
B
C
D
2.2
2.6
The Boxes
Opening where the Blast is introduced
Aperture where the melted iron runs off
Front Arch where the Furnace is worked

PLATE VI

Fig 1
Plan N° 4

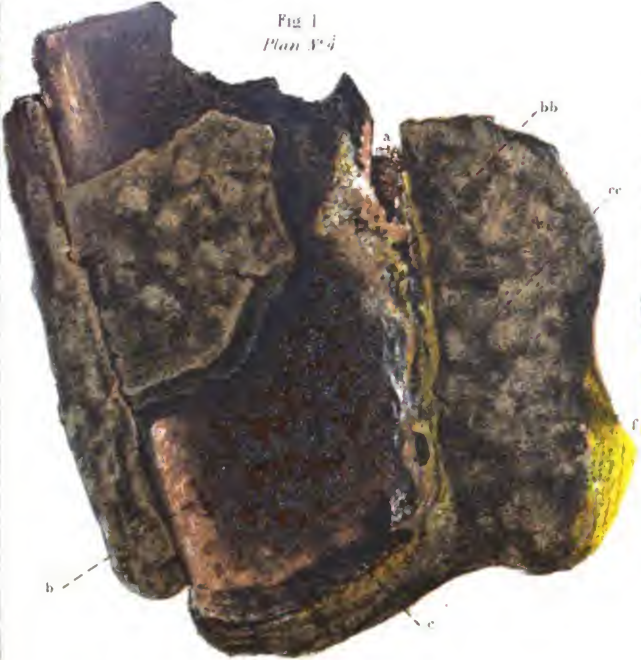


Fig 2
Plan N° 3

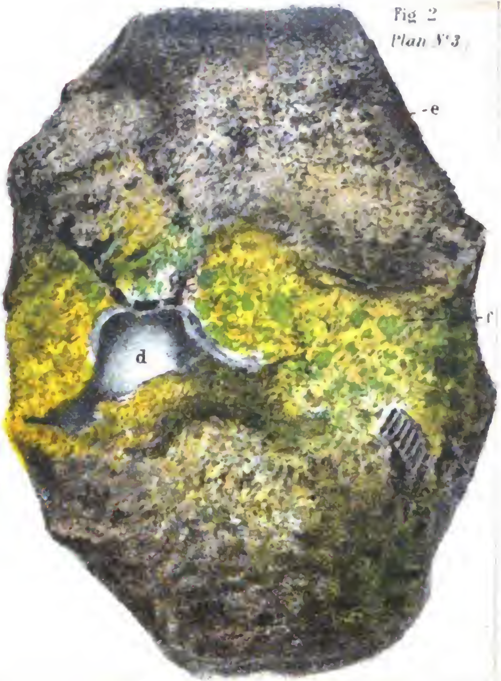


Fig 4
Plan N° 4

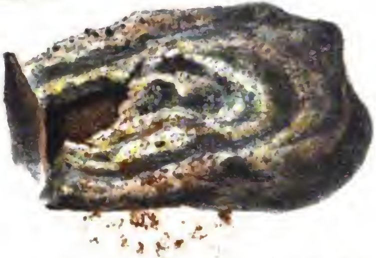


Fig 5
Plan N° 4

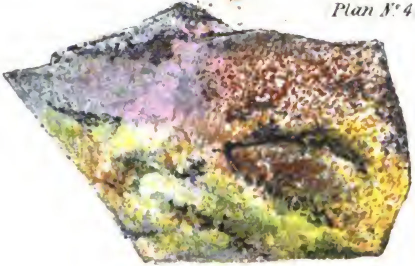


Fig 3
Plan N° 3

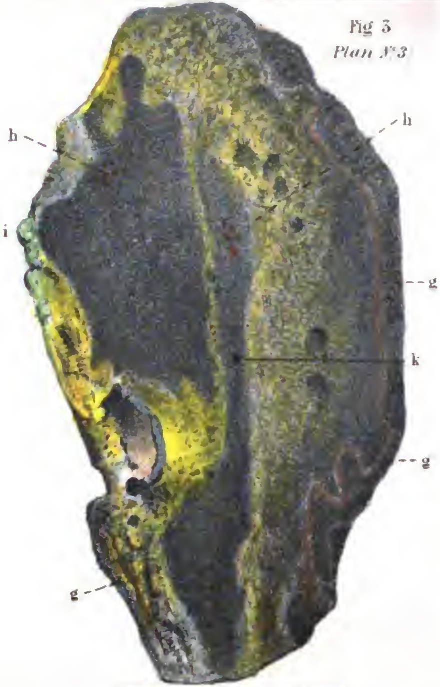


Fig. 6.
(Plan N° 2)

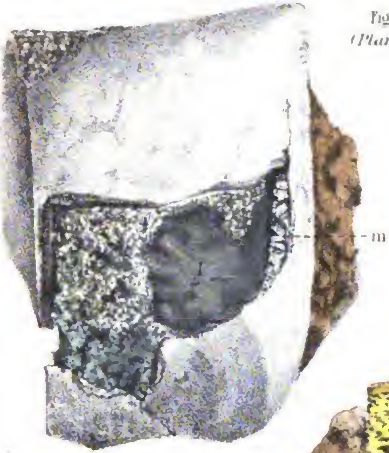


Fig. 8.
(Plan N° 1)

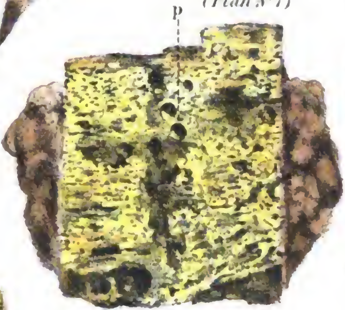
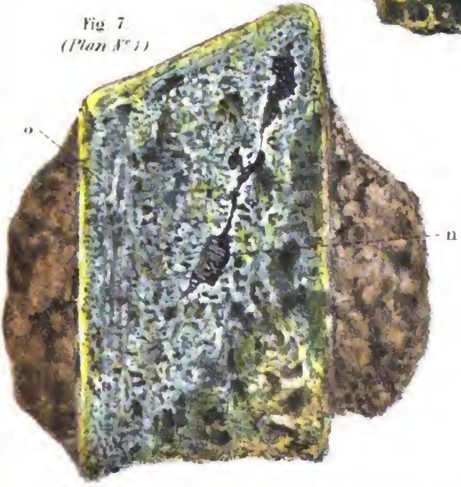


Fig. 7.
(Plan N° 1)



Second Report of the Committee on Steam-ship Performance.

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Table 2. Return of the results of performances of 49 vessels in the service of the Messageries Impériales of France during the year 1858.

Appendix No. II.—Table 1. Quarterly returns of the speed and consumption of coal of the London and North-Western Company's express and cargo boats, under regulated conditions of time, pressure, and expansion; from January 1 to December 31, 1859.

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Appendix No. III.—No. 1. Form of Log-book used by the Royal Mail Company.

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Appendix No. V. Letter from Mr. Archbold, Engineer-in-Chief, United States Navy. Description of the hull, engines, and boilers of the United States Steam Sloop 'Wyoming'.

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Table 2. Return of performance of the 'Wyoming' under steam and sail combined.

Table showing the trial performances of the steam-vessels 'Lima' and 'Bogota' when fitted with single cylinder engines, and after being refitted with double cylinder engines. Also the sea performances of the same vessels under both these conditions of machinery and on the same sea service.

REPORT.

AT the Meeting of the British Association, held in Aberdeen in September, 1859, this Committee was re-appointed in these terms:—

"That the following Members be requested to act as a Committee to continue the inquiry into the performance of steam-vessels, to embody the facts in the form now reported to the Association, and to report proceedings to the next meeting.

"That the attention of the Committee be also directed to the obtaining of information respecting the performance of vessels under sail, with a view to comparing the results of the two powers of wind and steam, in order to their most effective and economical combination.

"That the sum of £150 be placed at the disposal of the Committee for these purposes."

The following gentlemen were nominated to serve on the Committee:—

Vice-Admiral Moorsom.
The Marquis of Stafford, M.P.
The Earl of Caithness.
The Lord Dufferin.
William Fairbairn, F.R.S.
J. Scott Russell, F.R.S.
Admiral Paris, C.B.
The Hon. Capt. Egerton, R.N.
William Smith, C.E.
J. E. McConnell, C.E.
Charles Atherton, C.E.
Professor Rankine, LL.D.
J. R. Napier, C.E.
Richard Roberts, C.E.
Henry Wright, *Hon. Sec.*

Your Committee, having re-elected Admiral Moorsom to be their Chairman, beg leave to present the following Report:—

They have held monthly meetings, with intermediate meetings of sub-Committees appointed to carry out in detail matters referred to them by the General Committee. The Committee regret that they were deprived of the services of one of their members, Mr. Charles Atherton, at an early stage of the present inquiry, his public duties preventing his attending.

They have been assisted by Corresponding Members; noblemen and gentlemen, who, not being members of your Association, were not, by its rules, eligible as members of your Committee. Some of them, however, being owners of steam yachts, and others intimately acquainted with all matters relating to steam shipping, their cooperation was considered very essential, as introducing to the Committee gentlemen, not only capable of dealing with the subjects of this inquiry, but who also had it in their power to place in the hands of the Committee, materials, which, it is confidently hoped, will eventually lead to a correct and scientific knowledge of the laws governing economic Steam-Ship Performance.

The Corresponding Members so elected were:—

Lord Clarence Paget, M.P., C.B., &c.
Lord Alfred Paget, M.P.
Lord John Hay, M.P.
The Hon. L. Agar Ellis, M.P.
The Earl of Gifford, M.P.
The Marquis of Hartington, M.P.
Viscount Hill.
Capt. William Moorsom, R.N. (since deceased).
Mr. John Elder.
Mr. David Rowan.
Mr. J. E. Churchward.
Mr. Thomas Steele.

It will be within the recollection of the Association that the labours of this Committee last year were almost exclusively devoted to explaining to the various shipping companies and others with whom they were in correspondence, the objects proposed, and suggesting such forms as, if accurately filled in, would accomplish the purposes contemplated by the British Association. Log-books were prepared, and copies furnished to the leading Steam Packet Companies.

At their first meeting the Committee took into consideration the manner in which the grant of money placed at their disposal by the Association could be most judiciously applied, and after mature consideration it was unanimously resolved:—

"That to procure information from shipbuilders and engineers, it is found to be indispensable to hold personal intercourse with them, without which little progress is likely to be made."

The Honorary Secretary was accordingly deputed to wait upon the principal Shipbuilders, Engineers, and Steam Shipping Companies in London and its vicinity, to explain the objects of the Committee, and to solicit their cooperation by furnishing the Committee with authenticated returns of the sea performances of vessels, as well as of their trial trips.

In this your Committee are happy to report that they have succeeded. All to whom application was made expressed concurrence in the objects of your Committee, and their willingness to render every information in their power. The great difficulty was to make a suitable selection of vessels as examples of ordinary performance in the mercantile navy. Press of business, and perhaps want of thoroughly understanding the aims of the Committee, induced them to throw the whole labour of making these returns upon the Committee. The log-books for a number of years, and any documents the Committee desired to see, were freely placed at their service; but the time required to wade through the masses of logs, together with the fact of the Association meeting this year nearly three months earlier than usual, rendered it impracticable for more than a limited amount of work to be got through. It was therefore determined to make a selection of certain vessels, and to endeavour, as far as possible, to render complete the record of a few.

Your Committee at the same time communicated with the Admiralty, with a view of instituting a similar comparison between the trial trips and ordinary performances of Her Majesty's vessels at sea.

They much regret that they have not been able to obtain the latter. The Lords Commissioners, however, very courteously entrusted the Committee with the original returns of Her Majesty's vessels during the years 1857, 1858, and 1859, as furnished by the officers who conducted such trials, with permission to copy and make any use they thought fit of the information they contained. Diagrams of the engines taken on the trials during the year 1859 were also furnished.

Your Committee must remark with regard to these trial performances, that they do not appear to be instituted with any other view than as a trial of the *working* of the engines, excepting in a few instances, when experiments have been made to test the merits of certain screws. In very numerous cases, the officer distinctly reports that the boiler power is insufficient. The speed may or may not be taken at the convenience of the officers, but in no case is any note taken of the economical efficiency of the engines with regard to fuel.

As your Committee are restricted to a record of facts, it is out of place here to suggest changes in the mode of conducting the trials of Her Majesty's ships. The Committee would, however, fail in their duty if they did not avail themselves of this occasion to repeat their conviction, as expressed in their last Report,—"That it would tend to the advancement of science, the improvement of both vessels and engines, and to the great advantage of Her Majesty's service, if the trials of the Queen's ships were conducted on a more comprehensive plan, directed to definite objects of practical utility on a scientific basis, and recorded in a uniform manner."

In addition to the vessels of the British Royal and Mercantile Navies, your Committee have great pleasure in being enabled to lay before the British Association a return of forty-nine vessels in the service of the Messageries Impériales of France, obligingly furnished by a member of the Committee, Admiral Paris, and recorded in the form used by that Company; also, of two vessels belonging to the United States Navy, the particulars of which have been extracted from the second volume of Mr. Isherwood's recent publication, entitled "Engineering Precedents." They have been introduced into the Tables (see Appendix, Table I.).

While this Report was preparing, the Committee were gratified by receiving from Mr. Archbold, Engineer-in-Chief, United States Navy, two sets of tabulated returns of performance of the United States steam sloop of war 'Wyoming,' under steam alone, and under steam and sail.

These returns are of peculiar value, as comprising particulars in a form which the Committee believe has never yet been published. Along with the data afforded by Mr. Isherwood's book, they give the area of sail spread and the force of wind by notation, together with other particulars, useful for calculations of results and for comparisons.

These Tables are contained in the Appendix, with Mr. Archbold's letter, and a description of the hull, engines, and boilers of the 'Wyoming.'

The returns furnished by the British Admiralty embrace 216 vessels and 353 trials, with about 900 diagrams. For the same reason as above stated, in case of merchant vessels your Committee were obliged to make a selection, and to endeavour, for the purposes of the present Report, to obtain a complete record of a few, in the form suggested by the Committee. With this view, application was again made to the Admiralty, asking for the additional particulars not embraced in the returns of trial performances already furnished, and stating that their Lordships were, of course, aware that the particulars given in those documents were of comparatively small value without others of the vessels, their engines, screws, and boilers. The Committee added that they were in possession of such full particulars from both companies and private firms, and they trusted also to be favoured with similar information from the Admiralty. To this communication, the Lords Commissioners replied that they regretted they could not at present supply the information desired; but they would be glad to receive a copy of the reports obtained from companies and private firms. Your Committee thereupon constructed a Table embracing the particulars of merchant vessels (Appendix I., Table 1), and also a blank table filled in with the names of Her Majesty's vessels, selected as before mentioned, and containing the results of the test trials already given, and forwarded them to the Admiralty, begging that they might be favoured with the return of the table of the ships of war with the blanks filled in, adding, that if pressure of public business should prevent that being done, your Committee would send a person to copy the particulars on receiving the sanction of the Lords Commissioners to such a course.

As a measure of precaution in case of failure on the part of the Admiralty to send the promised particulars in time for printing, your Committee obtained returns of the machinery of these vessels by application to the manufacturers, personally and by letter. They avail themselves of this opportunity to thank Messrs. Boulton and Watt, Maudslay Sons and Field, and John Penn and Sons, for having so fully and so promptly responded to the call. They are, therefore, now enabled to lay before the Association a table comprising the results of the trials furnished by the Admiralty, together with the particulars of engines, &c., furnished by the manufacturers: the figures in Clarendon type (see Appendix I. Table 1) denote the Admiralty returns.

Your Committee regret that there are some particulars of the trials still wanting, as, for example, the evaporation of water and the consumption of fuel; but they believe that hitherto those items have not been recorded. It is earnestly hoped, now that public attention has been called to the subject, that a more exact and careful account may be taken, both on the measured mile and on ordinary service at sea.

In compiling the Table of merchant vessels, a similar course has been adopted, viz. of gathering from the best sources the various details necessary to complete the Table. The Companies to which the vessels belonged, gave every information in their possession, not only of the vessels themselves, but also of their actual sea performances, and placed at the disposal of the Committee the sea logs for every voyage, with permission to make such extracts as they deemed proper. For any additional information, they were referred to the constructors of the engines and vessels. Your Committee cannot speak in too high terms of the constant readiness to give information, although at considerable inconvenience to themselves, which the various Companies and private firms have invariably shown. They feel assured that, had time permitted, and if the requisite labour could be devoted to it, the whole shipping community would willingly contribute their quota of statistics: all that is wanted is uniformity of arrangement, and that a form similar to the one proposed by the Committee be generally adopted.

The thanks of the British Association are especially due to the Royal

Mail Steam Packet Company, to the Pacific Steam Navigation Company, to the London and North-Western Railway Company, to Messrs. Inglis Brothers, Messrs. Randolph and Elder, Messrs. Caird and Co., Messrs. R. Napier and Sons, and to Captain Walker, of the Board of Trade.

Captain Walker very obligingly placed at the service of the Committee some of the books in which the vessels registered and surveyed by the Board of Trade are recorded, and your Committee are in possession of copies of the entries of 51 vessels, varying from 600 to 2000 tons register and upwards, registered in the ports of London, Liverpool, Southampton, and Glasgow, during 1858. These have formed a very useful guide in leading to a selection of vessels from which to obtain the particulars requisite for comparison.

Your Committee have been in communication also with the French and American ambassadors, with a view to obtaining the statistics of performance of their respective navies; and, after referring the matter to their home Governments, the Committee have received the assurance of their willingness to cooperate.

Your Committee, being precluded by the terms of their appointment from discussing theories, or attempting to deduce laws, have, nevertheless, thought it not inconsistent to prepare a table of ratios based on the indicated horse-power, and showing the ratio between that element, as developed on the measured mile, and the grate, the tube, and other heating surfaces of the boilers producing it; also, between the grate and heating surfaces, and between the indicated horse-power and the coal consumed. The Committee regret that this important item, the coal, is not more frequently recorded, very few private trials making any note of it; and in no instance brought under the notice of the Committee, have the Admiralty officers made known this element, so necessary for ascertaining the efficiency of the boilers (for Table of Ratios, see Appendix IV. Table 1).

The following is a general summary of the result of the Committee's labours during the past session. They have obtained:—

1. Returns of 353 trials by 216 of Her Majesty's vessels of war during the years 1857, 1858, and 1859, with about 900 (898) diagrams taken during the trials in 1859; also notes, by the officers conducting the trials, of observed facts.

Of these trials, fifty-eight made by seventeen of the vessels, have been selected by way of illustration, with the particulars of machinery obtained from the makers, and arranged in a tabular form. (See Table I, Appendix I.) The names of the vessels are the 'Diadem,' 'Doris,' 'Mersey,' 'Marlborough,' 'Orlando,' 'Renown,' 'Algerine,' 'Bullfinch,' 'Centaur,' 'Flying Fish,' 'Hydra,' 'Industry,' 'James Watt,' 'Leven,' 'Lee,' 'Slaney,' and 'Virago.' This Table also comprises the two American vessels, 'Niagara' and 'Massachusetts,' together with the British vessel 'Rattler,' introduced for comparison.

2. Returns of 68 merchant vessels.

Four diagrams taken during trials of the 'Atrato.'

Scale of displacement of the 'Atrato.'

Lines of ditto.

Eight diagrams of the 'Shannon' taken during trials.

Twenty-two of these vessels have been selected and tabulated. (See Appendix I. Table 1.) Their names are—'Anglia,' 'Cambria,' 'Scotia,' 'Telegraph,' 'Mersey,' 'Paramatta,' 'Shannon,' 'Tasmanian,' 'Oneida,' 'Atrato,' 'La Plata,' 'Lima,' 'San Carlos,' 'Valparaiso,' 'Bogota,' 'Callao,' 'Guayaquil,' 'Undine,' 'Erminia,' 'Admiral,' 'Emerald,' and 'John Penn.'

The returns of the first four, belonging to the London and North-Western

Railway Company, are the mean of a number of trips on actual service between Holyhead and Kingstown. The returns of the 'Erminia,' 'Admiral,' 'Emerald,' and 'John Penn,' are measured mile performances only; but the remaining 12 vessels, with the exception of the 'Undine,' show their sea performances over distances of about 6000 consecutive nautical miles each, in addition to the performances on the measured mile.

3. Return of the results of performance of 49 vessels in the service of the Messageries Impériales of France, recorded in the form used by that Company. The whole of these vessels are given in the Appendix. (Appendix I. Table 2.)

4. Quarterly returns of the speed and consumption of coal of the London and North-Western Company's express and cargo boats, under regulated conditions of time, pressure, and expansion, from January 1st to December 31st, 1859—presented by Admiral Moorsom. (Appendix II. Table 1.)

Half-yearly verifications of the consumption of coal of the above vessels, from January 1st to December 31st, 1859, (Appendix II. Table 2.)

5. Forms of log-book used by the Royal Mail Company (Appendix III. No. 1), by the Pacific Steam Navigation Company (No. 2), by the Peninsular and Oriental Mail Company (No. 3), the Admiralty form for recording trials of Her Majesty's vessels (No. 4), and the Board of Trade form of return of capabilities (No. 5).

6. Table showing the ratio between the indicated horse-power and the grate, the tube, the other heating and total heating surfaces; also, between the grate and heating surfaces, and between the indicated horse-power and coal consumed. (Appendix IV.)

From the above list, it will be readily conceived that the time of the Committee has been fully occupied, as the task of copying and condensing from log-books is one involving a large amount of labour. Your Committee have not therefore, as yet, been enabled to conduct experiments on the plan recommended in their first Report presented to the Association in Aberdeen. They have, however, kept that branch of their inquiry in view; and through the courtesy of Mr. A. P. How, of Mark Lane, and of Messrs. Tylor and Sons, of Warwick Lane, they have been presented with apparatus of the value of about £60, consisting of salinometers, and an engine counter and clock; they have also at their disposal, for use whenever required, a superior dynamometer, and a compound stop-watch, and are now prepared to proceed with experiments, should the Association see fit to renew their powers, and the consent of the Government be obtained.

The Committee regret that they have not been able to collect any such information respecting the performance, under sail alone, of steam-vessels, as was contemplated by the Association, "with a view to comparing the results of the two powers of wind and steam, in order to their most effective and economical combination."

They must, however, draw attention to the synopsis given by Mr. Isherwood, of the steam-log of the 'Niagara,' in which her performances, "under steam alone," "under steam and fore-and-aft sails," and "under steam and square sails combined," are set forth in such manner that those conversant with the subject will be enabled, without much difficulty, to assign its approximate value to the power of the sails alone.

In Mr. Archbold's Table of the performance of the 'Wyoming,' the additional particulars of the force of the wind by notation, the area of sail set, and the indicated horse-power, which are not always stated in Mr. Isherwood's synopsis, afford the means of tolerably accurate comparison.

It is a duty the Committee owe to themselves, to express thus publicly their sense of the services rendered to the Association by Mr. Henry Wright, their Honorary Secretary, whose untiring energy, indefatigable labours, judgment, and discretion, have enabled them to lay this information before the meeting.

To Mr. Smith, a member of the Committee, their acknowledgements are due, as well for the use of a room in his offices, as for several sources of information opened to them by his influence.

The Marquis of Stafford, by placing a room in his house at the disposal of the Committee for occasional meetings, has contributed materially to the personal convenience of the members.

Of the grant of £150 voted by the Council of the Association, to defray the expenses of printing, postage, collecting information, &c., £124 3*s.* 10*d.* has been expended, viz.—

	£	*s.*	*d.*
To printing last year's Report	18	1	6
To printing present Report	78	14	0
To stationery and miscellaneous printing	13	15	9
To postage	5	0	1
To sundry expenses, including cab hire and railway fares, incurred	8	12	6
by the Honorary Secretary whilst collecting information	8	12	6
Total expenditure	£124	3	10
Balance of grant remaining unexpended	£25	16	2

It was originally intended to institute inquiries, not only in London and its vicinity, but also in Glasgow, Liverpool, Hull, Bristol, Southampton, Newcastle-on-Tyne, &c., and for this purpose it would have been necessary to defray the expenses of an agent to conduct the inquiry; but the shortness of the session, together with the extended field which London presents, rendered that course impracticable.

Your Committee feel, that a beginning having thus been made towards the means of a scientific investigation of the performance of ships under differing conditions at sea and in smooth water, it would ill become the British Association for the Advancement of Science to drop the question, although expense as well as trouble is involved in its successful pursuit.

They recommend the reappointment of a Committee, with a renewal of the grant, and with power to remunerate a clerk for such services as cannot be undertaken by any of its members.

On behalf of the Committee,
C. R. Moorsom, Vice-Admiral,
Chairman.

19 Salisbury Street, Strand, London,
June 13th, 1860.

Note.—Since the above Report was written, and whilst in the press, information was forwarded to the Committee which has enabled them to compile the Table given in the Supplementary Appendix, showing very interesting comparative results of two vessels, the 'Lima' and 'Bogota,' when fitted with different systems of machinery. The Table shows the results of performances on trial of these vessels when fitted with single-cylinder engines, and also at sea on a voyage of upwards of 6000 miles; also their performances when fitted with double-cylinder engines.

ERRATA.—Large Table—Appendix I.

'Atrato' on trial, Stokes Bay, Jan. 22, 1857, *omit* Indicated Horse power 1128·42.
Ditto, ditto, Mar. 4, 1857, *for* Indicated Horse power 1198·22 *read* 2396·44.

APPENDIX I.—TABLE 2. Results of Performances of the Steam-ships in

Name of vessel.	Nominal horse-power.	Corresponding number of revolutions.	Mean number of revolutions by counter.	Nominal power realized corresponding with number of revolutions obtained.	Total distance run.	Hours				Mean pressure of steam.	Mean vacuum in condenser.	Mean cut-off.
						Under steam.		Under weigh.				
				horses.	leagues.	h	m	h	m			
Thabor …………	370	24	20·00	308	4644	1557	25	1462	15	0·63	0·65	0·50
Sinai ……………	370	24	19·60	302	6672	2215		2077	50	0·51·5	0·66	0·45
Carmel …………	370	24	20·56	317	8658	2694	55	2556	15	0·65·5	0·64	0·42
Danube …………	370	63	63·06	370	8511	2725		2622	15	0·58	0·64	0·60
Cydnus …………	370	63	61·55	361	9607	3299	50	2786	10	0·66·7	0·63·5	0·64
Phase …………	370	63	64·72	380	3085	901	35	841		0·64	0·62	0·57
Pausilippe ………	320	26	23·86	293	7773	3799		2211	30	0·66·6	0·65	0·38
Guirinal …………	320	26	24·58	302	2968	1406	25	805	40	0·68	0·65	0·38
Euphrate ………	350	30	27·87	325	4668	1491	50	1400	40	0·61	0·65	0·46
Gange …………	300	29	26·88	278	9061	3403	55	2781	25	0·66	0·66	
Indus……………	300	50	46·10	276	8923	3394	45	2677	25	0·64	0·67	0·55
Hydaspe ………	240	30	27·42	219	5492	2168	35	1686	55	0·64	0·65	
Simoïs …………	240	46	47·48	247	6028	2416	30	1822	45	0·68	0·60	0·47
Jourdain ………	240	32	29·41	223	7082	3686	25	2359	50	0·73	0·66	0·35
Borysthène ……	240	32	28·31	216	6859	2634	45	2269	36	0·67	0·68	0·30
Méandre ………	240	32	29·78	223	8694	2973		2793		0·75	0·65	
Hermus…………	240	72	66·08	225	6201	2428	40	1967	10	0·69	0·63·5	0·48
Cephise …………	240	72	68·12	227	6336	2198	25	1911	55	0·76	0·63	0·50
Clyde……………	200	57	49·73	174	9477	3897	15	3108	45	0·49	0·68	0·50
Tamise …………	200	57	49·47	173	7778	3318	10	2537	10	0·48·6	0·68	0·51
Mersey …………	200	29	27·55	190	10572	4409		3514		0·50	0·65	0·38
Alexandre ………	220	21·5	20·73	212	5167	2144		1862		0·39	0·66·5	0·39
Caire ……………	220	21·5	19·74	202	5838	2136		2018	45	0·40	0·71	0·47
Egyptus…………	220	21·5	21·06	215	1545	577	30	525	20	0·41·6	0·67·5	
Louqsor …………	220	21	22·02	230	6196	2226	30	2107	30	0·49	0·70	0·39
Nil………………	220	21	20·47	214	4560	1834	20	1671	15	0·52	0·65	0·54
Osiris …………	220	21·5	20·70	211	4031	1571	30	1485	15	0·38	0·68	
Capitole ………	200	24	20·44	170	6956	3371		2168	55	0·66·5	0·67	0·39
Vatican …………	200	24	20·19	168	7424	3705	10	2320	25	0·64	0·67	0·30
Henri IV. ………	200	45	46·32	206	5474	3336		1969		0·66	0·66	0·51
Sully ……………	200	45	47·91	213	6523	2882	35	2285	30	0·65	0·62·5	0·59
Bosphore ………	180	26·5	26·82	182	6106	2411	10	1924	10	0·59	0·64	0·38
Hellespont ……	180	26·5	27·62	187	3244	1327	20	1017		0·65	0·60	0·30
Oronte …………	180	25	24·08	173	4320	2078	15	1424	40	0·60	0·63	0·53
Philippe Auguste	180	26·5	27·05	183	6870	2472		2162	35	0·55	0·65	0·44
Merovée…………	180	25	23·25	167	4218	2128	45	1489	30	0·57	0·66	0·34
Cheliff …………	180	46	45·92	179	6308	2607	30	2206	30	0·61	0·69	0·41
Mitidja …………	160	50	47·75	152	5795	2338		1989	30	0·62	0·66	0·44
Aventin…………	160	26	27·12	166	5393	1930		1646	15	0·48	0·62	0·30
Balkan …………	160	28	27·38	156	5370	2250	30	1630	15	0·82	0·65	0·40
Taurus …………	160	28	27·48	157	2068	937	40	847	30	0·87	0·63	0·55
Leonidas………	160	22·5	28·14	129	890	410	45	385	50	0·50	0·66	0·40
Scamandre ……	160	22·5	18·00	128	1174	668	55	522	35	0·53	0·68	0·42
Sphinx …………	160	30·5	25·35	132	5512	2697	35	1905	30	0·37	0 66	
Tago ……………	160	22·5	20·25	144	5454	2563		2124		0·40	0·66	
Tancrède ………	160	22·5	17·85	126	1233	839	10	497	40	0·42	0·68	
Télémaque ……	160	22·5	22·49	159	6129	2580		2372		0·48·5	0·66	
Amsterdam ……	150	24	20·33	127	5104	2543		1904		0·56	0·63	0·40
Périclés ………	120	27·5	27·94	121	6374	2528	20	2125	55	0·55	0·64	0·40
Totals ………	11160	…	…	10438	284945	116152	30	92733		…	…	…
Means ………	227	…	…	213	5815	2370		1893		…	…	…

NOTE.—Metre = 3·2809 feet = 39·3702 inches.

the Service of the "Messageries Impériales" of France during the year 1858.

Mean draft.	Difference of draft.	Consumption of coal.					Consumption of oil and tallow.		Mean speed obtained.	Mean speed estimated.	Consumption of fuel per mile reduced to the speed of nine knots.	Distance run with 1000 kilogrammes of coal at the speed of nine knots.
		Total.	Mean per hour.	Mean per nautical mile.	Per nominal horse-power per hour.	Per realized horse-power per hour.	Total.	Per horse-power per 24 hours.				
mèt.	mèt.	kilo.	kilo.	kilo.	kilo.	kilo.	kilo.	kilo.	knots.	knots.	kilo.	mètres.
4·15	0·08	2,167,966	1483	465	4·0	4·8	3122	0·139	9·60	...	417	13,517
4·14	0·18	2,889,775	1390	432	3·7	4·6	6007	0·188	9·63	10·05	378	14,684
3·92	0·22	3,916,147	1533	450	4·1	4·8	7113	0·172	10·20	10·25	352	15,766
4·05	1·29	3,274,191	1248	384	3·4	3·4	8140	0·201	9·75	10·00	328	16,939
4·04	1·34	3,981,000	1430	411	3·8	3·9	6933	0·159	10·35	10·52	313	17.729
3·84	1·52	1,408,823	1675	416	4·5	4·4	2478	0·195	11·05	...	303	18,311
3·92	0·38	3,508,304	1586	462	4·9	5·4	5137	0·174	10·55	11·15	329	16,878
3·88	0·28	1,232,000	1529	414	4·7	5·0	1990	0·186	11·05	11·74	275	20,181
5·29	1·16	2,257,560	1605	489	4·5	4·9	3182	0·156	10·00	10·05	291	14,181
5·01	1·65	4,302,349	1547	477	5·1	5·5	4939	0·149	9·76	...	404	13,741
4·98	0·92	4,378,666	1644	495	5·4	5·9	6952	0·208	10·02	...	396	14,025
4·57	0·62	1,906,185	1130	345	4·7	5·1	3905	0·230	9·77	10·25	294	18,843
4·55	0·85	2,227,342	1222	369	5·0	4·9	4109	0·225	9·95	...	303	18,299
5·00	1·10	3,003,979	1268	423	5·3	5·6	4837	0·218	9·00	9·80	424	13,096
4·67	0·80	2,757.184	1215	336	5·0	5·6	5389	0·237	9·08	9·27	394	14,096
4·76	0·67	3,336,095	1191	387	4·9	5·3	5282	0·185	9·34	...	356	15,592
3·48	1·21	1,983,785	1008	318	4·2	4·4	4906	0·245	9·50	10·27	287	19,341
3·52	1·33	1,906,803	997	300	4·1	4·3	4151	0·217	9·95	10·62	246	22,547
3·90	1·66	2,950,203	949	309	4·7	5·4	4749	0·176	9·22	9·58	296	18,713
4·07	1·89	2,470,000	972	315	4·8	5·6	3947	0·184	9·25	...	300	18,472
4·43	0·55	3,692,912	1051	348	5·2	5·5	3379	0·120	9·02	9·50	348	15,962
4·10	0·14	1,935,570	1038	393	4·7	4·8	4068	0·238	8·32	9·04	438	12,673
4·21	0·10	2,180,496	1082	372	4·9	5·3	2991	0·161	8·67	9·23	402	13,804
4·11	0·18	543,000	1026	348	4·6	4·7	665	0·137	8·91	...	359	15,484
4·11	0·10	2,268,404	1076	366	5·9	4·6	4444	0·227	8·82	9·11	381	14,575
4·13	0·16	1,704,550	1020	372	4·6	4·7	2338	0·157	8·20	9·00	450	12,338
4·06	0·09	1,414,570	959	348	4·3	4·5	2262	0·165	8·14	8·40	429	12,945
3·43	0·09	2,372,294	1093	339	5·4	6·4	4338	0·238	9·62	9·70	298	18,639
3·29	0·10	2,628,810	1132	354	5·6	6·7	3849	0·197	9·60	...	311	17,820
3·41	1·61	1,688,672	857	306	4·2	4·1	5381	0·321	8·35	...	358	15,494
3·53	1·56	961,356	857	300	4·2	4·0	4384	0·226	8·56	...	332	16,715
2·93	0·20	1,894,091	989	309	5·4	5·4	3341	0·231	9·55	10·40	275	20,165
3·05	0·14	987,162	970	303	5·3	5·1	1355	0·182	9·56	10·45	269	20,595
2·91	0·14	1,247,076	875	288	4·8	5·0	2730	0·262	9·10	9·10	282	19,668
2·90	0·15	2,121,939	981	306	5·4	5·3	4519	0·280	9·53	10·15	275	20,160
3·06	0·15	1,418,184	952	336	5·3	5·7	2356	0·228	8·50	...	277	14,723
3·46	1·37	2,027,570	919	321	5·1	5·1	3855	0·232	8·57	9·19	354	15,667
3·64	0·98	1,624,569	817	279	5·1	5·3	3153	0·248	8·73	9·31	297	18,652
3·07	0·30	1,441,148	875	267	5·4	5·2	2766	0·247	9·83	10·27	224	24,802
2·55	0·05	1,512.670	927	279	5·7	5·9	2567	0·226	9·90	10·37	232	23,856
2·39	0·11	647,553	764	246	4·7	4·8	1297	0·233	9·40	...	224	24,781
3·52	0·07	272,378	685	303	4·3	5·3	425	0·168	7·04	...	499	11,120
3·55	0·02	398,775	756	333	4·7	5·9	1191	0·352	6·85	...	586	9,469
3·01	0·45	1,399,284	787	270	4·9	5·9	3928	0·311	8·67	...	293	18,985
3·53	0·25	1,728,461	823	212	5·0	5·7	5327	0·365	8·00	...	401	13,851
3·46	0·05	305,741	623	282	3·9	4·9	422	0·130	7·48	...	359	15,460
3·57	0·21	2,025,500	853	330	5·3	5·5	4674	0·298	7·75	...	445	12,465
3·13	0·49	1,259,626	709	261	4·7	5·5	2701	0·229	8·34	8·81	287	19,318
2·41	0·14	1,350,790	635	210	5·2	5·2	2914	0·275	9·00	9·30	211	26,208
...	...	102,011,500	52746	17117	...	...	184943	10·521	...	...	16782	831,295
3·46	**0·33**	**2,081,867**	**1099**	**358**	**4·8**	**5·1**	**3774**	**0·214**	**9·21**	**9·82**	**342**	**16,945**

Kilo. = 2·20549 lbs. Avoirdupois.

Appendix II.—Table 1. Chester and Holyhead Railway—Steam-boat Express and Cargo Boats, under regulated conditions of Time,

Vessel.	Date.	No. of trips run.	Passages.			Average rate of speed—miles.	Actual weight on valves.
			Longest.	Shortest.	Average.		
	1859.		h m	h m	h m		lbs.
Express:							
Anglia	1 Jan. to 31 March ...	73	8 24*	4 0	4 42	13·40	15
	1 April to 30 June ...	47	7 30	4 20	4 37	13·64	15
	1 July to 30 Sept. ...	nil.					
	1 Oct. to 31 Dec.	36	5 26	4 24	4 49	13·08	15
Cambria	1 Jan. to 31 March ...	nil.					
	1 April to 30 June ...	36	5 29	4 17	4 31	13·95	15
	1 July to 30 Sept. ...	75	5 16	4 13	4 27	14·15	15
	1 Oct. to 31 Dec.	44	5 55	4 21	4 41	13·45	15
Scotia............	1 Jan. to 31 March ...	81	7 28*	4 6	4 45	13·26	15
	1 April to 30 June ...	34	6 48	4 16	4 40	13·50	15
	1 July to 30 Sept. ...	nil.					
	1 Oct. to 31 Dec.	41	6 15	4 20	4 49	13·08	15
Telegraph	1 Jan. to 31 March ...	nil.					
	1 April to 30 June ...	37	5 0	4 7	4 30	14·03	10
	1 July to 30 Sept. ...	83	6 7	4 11	4 40	13·50	10
	1 Oct. to 31 Dec.	40	6 0	4 27	4 58	12·68	10
Cargo:							
Hibernia	1 Jan. to 31 March ...	77	9 17	5 40	6 44	10·39	15
	1 April to 30 June ...	76	9 27	5 44	6 28	10·83	15
	1 July to 30 Sept. ...	63	8 33	5 45	6 35	10·63	15
	1 Oct. to 31 Dec.	77	12 15	5 40	6 47	10·31	15
Hercules	1 Jan. to 31 March ...	26	11 15	6 15	7 55	8·84	12
	1 April to 30 June ...	37	9 25	5 55	6 22	10·41	12
	1 July to 30 Sept. ...	75	12 45	6 0	7 27	9·39	12
	1 Oct. to 31 Dec.	49	13 35	6 35	8 16	8·46	12
Ocean..	1 Jan. to 31 March ...	71	10 0	7 15	8 3	8·48	10
	1 April to 30 June ...	7	8 5	7 0	7 28	9·37	10
	1 July to 30 Sept. ...	28	11 15	6 0	6 57	10·07	10
	1 Oct. to 31 Dec.	32	11 15	6 15	7 33	9·27	10
Sea Nymph	1 Jan. to 31 March ...	56	13 5	5 45	6 56	10·09	12
	1 April to 30 June ...	65	7 35	5 30	6 14	11·23	12
	1 July to 30 Sept. ...	75	7 30	5 20	6 7	11·44	12
	1 Oct. to 31 Dec.	91	8 20	5 20	6 30	10·76	12

Department.—A Return of the Speed and Consumption of Coal of the Pressure, and Expansion, for the undermentioned Period.

Average pressure worked at.	Proportion of steam in cylinder.	Coals consumed.									Remarks.
		Per trip, including getting up steam and while lying at Holyhead.			Per hour, including raising steam, banking fires, &c.			Per hour, exclusive of raising steam, banking fires, &c.			
lbs.		tons	cwt.	lbs.	tons	cwt.	lbs.	tons	cwt.	lbs.	
$12\frac{1}{2}$	$\frac{15}{36}$ $\frac{16}{36}$ $\frac{18}{36}$	12	11	12	2	13	47	2	1	35	* Heavy gale, W.N.W. Eased engines.
13	$\frac{16}{36}$ and none	11	17	14	2	11	40	1	19	28	
$12\frac{1}{4}$	$\frac{16}{36}$ and none	12	10	3	2	11	101	1	19	79	
$13\frac{1}{2}$	$\frac{26}{36}$	11	15	37	2	12	11	1	19	80	
$13\frac{1}{2}$	$\frac{26}{36}$	12	2	11	2	14	33	2	1	50	
$13\frac{1}{2}$	$\frac{26}{36}$	13	17	66	2	19	28	2	6	45	
12	$\frac{15}{36}$ $\frac{18}{36}$ $\frac{21}{36}$	13	13	59	2	17	65	2	5	63	* Heavy gale, W.N.W. Eased engines.
$12\frac{1}{2}$	$\frac{18}{36}$ and $\frac{26}{36}$	12	9	98	2	15	100	2	3	98	
$10\frac{3}{4}$	$\frac{18}{36}$	13	13	71	2	16	90	2	4	71	
$10\frac{1}{2}$	……………	12	17	60	2	17	15	2	4	35	
10	none	13	10	44	2	17	98	2	5	10	
$9\frac{3}{4}$	none	14	13	25	2	19	41	2	6	65	
$7\frac{1}{2}$	$\frac{13}{36}$	13	18	11	2	1	33	1	13	13	
7	$\frac{13}{36}$	13	13	54	2	2	32	1	14	12	
$7\frac{1}{2}$	$\frac{13}{36}$	14	15	96	2	4	101	1	16	78	
$7\frac{1}{2}$	$\frac{13}{36}$	14	13	23	2	4	23	1	16	0	
$10\frac{1}{2}$	none	8	11	64	1	1	75		17	98	
11	……………	8	8	6	1	6	18	1	2	41	
11	none	7	19	28	1	1	40		17	39	
$10\frac{1}{4}$	none	9	0	20	1	1	89		17	88	
9	none	9	2	32	1	2	72		18	19	
9	……………	11	12	64	1	11	16	1	6	75	
$8\frac{1}{2}$	none	9	17	24	1	8	36	1	3	83	
$8\frac{1}{2}$	none	11	2	21	1	9	48	1	4	95	NOTE.—Orders are given to the vessels, in gales and heavy head sea, to ease the engines, which occasionally increases the average passage.
10	2nd grade	11	7	24	1	12	86	1	4	45	
10	1 and 2 grade	10	8	61	1	13	51	1	5	10	
10	1 and 2 grade	10	11	20	1	14	54	1	5	6	
$9\frac{3}{4}$	1 and 2 grade and full speed	11	13	12	1	15	39	1	6	103	

APPENDIX II.—TABLE 2. Chester and Holyhead Railway—Steam-boat Department.—Chester and Holyhead Steam-boats' Consumption of Coal for the Six Months ending 30th June, 1859.

Name of vessel.	Three months ending	Number of trips.	Average number of tons each trip.	Total for the six months.	Total as shown by general account, including coal on board.
	1859.		tons cwt. lbs.	tons cwt. lbs.	tons cwt. lb.
Anglia	March 31...	73	12 11 12	1473 15 78	1458 8 0
	June 30 ...	47	11 17 14		
Cambria	March 31.				
	June 30 ...	36	11 15 37	423 11 100	426 4 0
Scotia	March 31...	81	13 13 59	1532 11 47	1575 13 0
	June 30 ...	34	12 9 98		
Telegraph	March 31.				
	June 30 ...	37	12 17 60	476 8 92	498 12 0
Hibernia	March 31...	77	13 18 11	2109 18 23	2104 19 0
	June 30 ...	76	13 13 54		
Hercules	March 31...	26	8 11 64	533 18 94	525 15 0
	June 30 ...	37	8 8 6		
Ocean	March 31...	21	9 2 32	272 16 0	285 11 0
	June 30 ...	7	11 12 64		
Sea Nymph......	March 31...	56	11 7 24	1313 19 45	1327 1 0
	June 30 ...	65	10 8 61		
				8137 0 31	8202 3 0

APPENDIX II.—TABLE 3. Chester and Holyhead Railway—Steam-boat Department.—Chester and Holyhead Steam-boats' Consumption of Coal for the Six Months ending 31st December, 1859.

	1859.		tons cwt. lbs.	tons cwt. lbs.	tons cwt. lb.
Anglia	Sept. 30.				
	Dec. 31 ...	36	12 10 3	450 0 108	449 17 0
Cambria	Sept. 30 ...	75	12 2 11	1518 11 33	1496 10 0
	Dec. 31 ...	44	13 17 66		
Scotia	Sept. 30.				
	Dec. 31 ...	41	13 13 71	560 18 111	568 6 0
Telegraph	Sept. 30 ...	83	13 10 44	1708 11 60	1688 3 0
	Dec. 31 ...	40	14 13 25		
Hibernia	Sept. 30 ...	63	14 15 96	2060 15 91	2074 16 0
	Dec. 31 ...	77	14 13 23		
Hercules	Sept. 30 ...	75	7 19 28	1037 12 56	1048 10 0
	Dec. 31 ...	49	9 0 20		
Ocean	Sept. 30 ...	28	9 17 24	631 12 0	640 1 0
	Dec. 31 ...	32	11 2 21		
Sea Nymph......	Sept. 30 ...	75	10 11 20	1852 11 16	1861 3 0
	Dec. 31 ...	91	11 13 12		
				9820 14 27	9827 6 0

APPENDIX III.—TABLE 1. Log of the West India Royal Mail Steam Packet Company's Ship ____________

From ____________ ____________ during ________ day, the ____ day of ____________ 18__.

Hours.	Courses.	Knots.	Fathoms.	Winds.	No. of sails set.	Coals consumed per watch.	Height of steam-gauge.	Revolutions per minute.	Revolutions per watch.	Mean height of engine barometer.	Every four hours.					Degree of expansive working hourly.	Hourly consumption of coals, say in weight.	REMARKS. In this column is to be minutely noted every circumstance connected with the Company's service.
											Duration of engineer's watch.	Temperature of hot wells.	Density of water in boiler before blowing off.	Average height of water in boilers.	Engineers in charge.			

Course.	Distance.	Difference of latitude.	Departure.	Latitude account.	Latitude observed.	Difference of longitude.	Longitude account.	Longitude chronom.	Longitude observed.	Variation.	

	Coals.	Tallow.	Oil.	Water.
Description.	tons cwt. lbs.	cwt. lbs.	gals. pts. gills.	gallons.
Quantity on charge.				
Expended since noon yesterday.				
Remains.				

No. of hours steam up.	No. of hours sails set.	Immersion.		Distance run per patent log.
		Forward.	Aft.	

Waste ashes and clinkers.	Bearing and distance at noon.

APPENDIX III.—TABLE 2. Steamer ________________, Voyage No. _____.

Return by the Commander, First Officer, and Engineer of the Pacific Steam Navigation Company's Steam-ship ______________ for a Voyage from Panama to Valparaiso and back to Panama.

Commenced the ___ day of __________, 18__, at ___________, and ended the ___ day of __________, 18__, at ___________.
Time occupied, ______ days ___ hours.

	Arrivals.			Departures.					Average					Received on board.					Remarks (which may be continued on the other side).
Ports visited during the voyage.	Date.	Hour.	Draught of water.	Date.	Hour.	Draught of water.	Stoppage.	Under weigh.	Speed per hour.	Consumption of fuel per hour.	Pressure of steam.	No. of strokes per hour.	No. of revolutions from port to port.	Coals.	Sperm oil.	Common oil.	Tallow.	Cotton waste.	Here state the condition of hull and machinery; the cause of delay, if any should occur; the quality and description of coal, patent fuel, &c.
Quantity remaining on board from last voyage.			ft. in.			ft. in.	h m	h m						t. cwt.	gls.	gls.	lbs.	lbs.	
Totals.............................																			
Quantities consumed { Engine Department .... Sailing Department																			
Remaining on board at the termination of the voyage.																			

We have examined the above, compared it with the quantities remaining on board, and found it correct.

_____________________ Commander.
_____________________ First Officer.
_____________________ First Engineer.

_____________________ Overseer.
_____________________ Superintendent Engineer.

APPENDIX III.—TABLE 3. Peninsular and Oriental Company's Engineer's Log.

Date.	Hour.	Watch.	Pressure of steam.	Grade of expansion.	No. of strokes per minute per watch.	Vacuum.	Height of water in boilers.	Density of water.	Dip of paddles at starting.	Number of boilers at work.	Temperature of condensers.	Temperature of engine room.	Consumption of coals per hour.	Sails set.	Observations.

APPENDIX III.—TABLE 4.

______________ Yard.

Report of trial of Her Majesty's steam vessel ______________

Date ____________

When tried ....
Where tried ....
Draught of water... { Forward ....
Draught of water... { Aft ....
Number of revolutions of the engines ....
Pressure on safety valve.......................................
Vacuum in Condensers ....
Power as shown by indicator....................................
Speed of vessel..

__________ Indicator cards and __________ tracings are attached to this Report.

Remarks as to the performance of the engines, boilers, &c.

No. of runs.	Revolutions of engines per minute.	Observed time.		Speed due to time.	Mean speeds.	True mean speeds.
		Min.	Sec.			
1						
2						
3						
4						
5						
6						
Mean revolutions...					Knots mean of means.	

Note—Appendix III. No. 5 carried to bottom of Tables opposite page 216.

Appendix IV.—Table showing the Ratios between the indicated Horse-
indicated Horse-power; also, between the grate and heating sur-

Name of vessel.	Place and nature of performance.	Speed.	
		Statute miles.	Knots.
Vessels of the United States Navy.			
Niagara (screw)	Performance in smooth water	12·56	109·00
„	Ordinary actual performance at sea under steam alone	8·06	7·003
„	Ditto ditto, steam and square sail combined	11·51	9·988
„	Ditto ditto, steam and fore-and-aft sails	8·55	7·425
„	Mean of the above sea performance	9·75	8·459
Massachusetts (screw)	Performance in smooth water	7·948	6·900
„	Ordinary performance at sea under steam alone	5·597	4·859
„	Ditto ditto, steam and sail combined	8·268	7·177
„	Mean of the above sea performances	6·469	5·616
Vessels of the Royal Navy.			
Rattler (screw)	On trial, Thames, Sept. 5, 1844	11·605	10·074
„	Ditto ditto Jan. 1845	11·104	9·639
„	Ditto ditto Sept. 5, 1851	11·255	9·770
„	Ditto ditto Sept. 5, 1851	10·530	9·141
Diadem (screw)	Ditto, Stokes Bay, Oct. 20, 1857	13·30	11·633
„	Ditto ditto Oct. 21, „	13·43	11·661
„	Ditto ditto Nov. 7, „	13·54	11·754
„	Ditto ditto Dec. 1, „	13·72	11·912
„	Ditto ditto Jan. 1, 1858	13·70	11·899
„	Ditto ditto April 16, 1858	13·82	12·003
Doris (screw)	Ditto, Stokes Bay, May 27, 1859	14·123	12·26
„ (with common screw)	Ditto ditto April 21, „	13·620	11·823
„ (common screw increased to 20)	Ditto ditto May 5, „	13·623	11·826
„ (Ditto, with two foremost corners cut off)	Ditto ditto May 9, „	13·879	12·048
„ (Ditto, with four corners cut off)	Ditto ditto May 23, „	13·837	12·012
„ (Griffiths' screw)	Ditto ditto May 25, „	13·802	11·981
„ (Ditto ditto)	Ditto ditto May 27, „	14·130	12·266
„ (Ditto ditto)	Ditto ditto June 3, „	14·006	12·158
Marlborough (screw)	Ditto, Stokes Bay, June 1, 1859	12·94	11·233
„	Ditto ditto June 2, „	12·92	11·217
„ (with half-boiler power)	Ditto ditto June 2, „	10·62	9·219
„	Ditto ditto May 28, „	12·24	10·625
Mersey (screw)	Ditto, Stokes Bay, March 23, 1859	15·31	13·290
Renown (screw)	Ditto, Stokes Bay, April 19, 1858	12·902	11·2
„	Ditto, between Sheerness and Nore, October 5, 1857	12·533	10·88
„	Ditto, between Sheerness and Sunk Light, October 5, 1857	12·533	10·88
„	Ditto, between Sheerness and Swim Middle, October 30, 1857	14·573	12·65
„	Ditto, down the Swim, October 30, 1857	14·573	12·65

power and the Grate, the Tube, the other heating and total heating surfaces and the faces, and between the indicated Horse-power and the Coal consumed.

Horse-power.		Ratio of nominal to indicated horse-power.	Ratio of indicated to nominal horse-power.	Ratio of grate-surface to indicated horse-power.	Ratio of tube-surface to indicated horse-power.	Ratio of other heating surface to indicated horse-power.	Ratio of total heating surface to indicated horse-power.	Ratio of heating surface to grate-surface.	Ratio of other heating surface to tube-surface.	Coal consumed per hour per indicated horse-power.	Water evaporated per hour per indicated horse-power.	Water evaporated per hour per lb. of fuel.
Indicated.	Nominal.											
										lbs.	lbs.	lbs.
1955·09	700	·358	2·793	·247	6·556	2·192	8·748	35·336	·334	3·529		
879·28	700	·796	1·256	·554	14·577	4·873	19·451	35·336	·334	4·617	41·813	9 058
773·65	700	·905	1·105	·625	16·567	5·538	22·107	35·336	·334	4·904	42·743	8·716
837·31	700	·836	1·196	·578	15·308	5·117	20·426	35·336	·334	4·987	42·156	8·452
824·48	700	·849	1·178	·587	15·546	5·197	20·744	35·336	·334	4·790	42·269	8·597
240·74	...	...	...	·361	Flue boilers	10·280	10·281	28·448	...	4·029		
168·81	...	...	...	·514		14·661	14·661	28·448	...	4·401		
149·61	...	...	...	·588		16·543	16·543	28·448	...	4·491		
162·54	...	...	...	·535		15·227	15·227	28·448	...	4·429		
428	200	·467	2·140									
436·7	200	·458	2·184									
499·2	200	·401	2·496									
519·2	200	·385	2·596									
2324·42	800	·344	2·906	·234	5·131	·991	6·122	26·16	·193			
2325·96	800	·343	2·907	·234	5·035	·987	6·022	26·16	·193			
2663·60	800	·300	3·330	·204	4·478	·865	5·343	26·16	·193			
2587·50	800	·309	3·234	·210	4·609	·894	5·503	26·16	·193			
2685·04	800	·298	3·356	·203	4·441	·858	5·299	26·16	·193			
2979	800	·268	3·724	·183	4·004	·773	4·777	26·16	·193			
3091	800	·259	3·864	·176	*	...	4·659	26·47				
2921·2	800	·278	3·652	·186	...	...	4·929	26·47				
2788·4	800	·287	3·486	·195	...	...	5·164	26·47				
2884·4	800	·278	3·606	·189	...	...	4·992	26·47				
2920·32	800	·274	3·650	·186	...	...	4·931	26·47				
2825·6	800	·283	3·532	·192	...	...	5·096	26·47				
3091·1	800	·259	3·864	·176	...	...	4·658	26·47				
3009·03	800	·266	3·761	·188	...	...	4·786	26·47				
3022	800	·265	3·778	·180	3·947	·762	4·709	26·16	·193			
3054·26	800	·262	3·818	·178	3·905	·754	4·659	26·16	·193			
1722·08	800	·465	2·153	·316	6·926	1·338	8·264	26·16	·193			
2738·94	800	·292	3·424	·199	4·355	·841	5·196	26·16	·193			
4044	1000	·247	4·044	·168	3·702	·736	4·438	26·40	·198			
3183	800	·251	3·979	·171	*	...	4·524	26·47				
2864·75	800	·280	3·581	·190	...	...	5·027	26·47				
2759·95	800	·290	3·450	·197	...	...	5·218	26·47				
2837·36	800	·282	3·547	·192	...	...	5·075	26·47				
2793	800	·286	3·491	·195	...	...	5·156	26·47				

* Particulars of the tube-surface were not furnished by the manufacturers of the engines.

TABLE (*continued*).

Name of vessel.	Place and nature of performance.	Speed.	
		Statute miles.	Knots.
Renown (screw)	On trial, Stokes Bay, March 15, 1858	13·167	11·43
,, (with half-boiler power)	Ditto ditto March 16, ,,	10·535	9·145
,,	Ditto ditto April 19, ,,	13·611	11·815
Orlando (screw)	Ditto, Plymouth, August 22, 1859	14·97	13·000
,,	Ditto, outside Breakwater, Oct. 7, 1859	15·16	13·160
Algerine (screw)	Ditto, Stokes Bay, April 9, 1858	10·71	9·300
Leven (screw)	Ditto, Stokes Bay, April 29, 1858	10·68	9·270
Lee (screw)	Ditto, Stokes Bay, April 13, 1858	10·68	9·270
Slaney	Ditto, Stokes Bay, April 28, 1858	10·77	9·350
Flying Fish (screw)	Ditto, Stokes Bay, June 20, 1858	13·52	11·736
,,	Ditto ditto June 30, ,,	12·43	10·794
,,	Ditto ditto July 2, ,,	12·70	11·025
,,	Ditto ditto July 6, ,,	12·56	10·908
,,	Ditto ditto July 8, ,,	12·71	11·038
,,	Ditto ditto July 10, ,,	13·29	11·536
James Watt (screw)	Ditto in Basin (Keyham), Mar. 28, 1859	...	...
,,	Ditto outside Breakwater (Keyham) May 4, 1859	...	...
Virago (paddle)	Ditto in Basin (Keyham), Sept. 6, 1858	...	...
,,	Ditto outside Breakwater, Sept. 18, 1859	...	...
,,	Ditto in Basin (Keyham), Sept. 1, 1859	...	...
Hydra (paddle)	Ditto between Sheerness and Sunk Light, March 23, 1858	11·60	10·068
,,	Ditto outside Breakwater (Keyham), November 8, 1858	...	...
Centaur (paddle)	Ditto in Basin (Keyham), July 13, 1859	...	...
,,	Ditto outside Breakwater, Oct. 22, ,,	...	...
Industry (screw)	Ditto Long Reach, Jan. 12, 1858	8·41	7·300
,,	Ditto Lower Hope, Aug. 24, 1858	10·50	9·120
Bullfinch (screw)	Ditto, Lower Hope, March 5, 1856	10·13	8·800
,, (Griffith's propeller, with inclined blades)	Ditto ditto June 24, 1857	9·71	8·423
,, (Ditto ditto ditto)	Ditto ditto June 26, ,,	9·36	8·121
,, (Lowe's propeller)	Ditto ditto Sept. 10, ,,	8·57	7·442
,, (Ditto ditto)	Ditto ditto March 20, 1858	9·83	8·534
,, (Medwin's propeller)	Ditto, Stokes Bay, July 8, 1859	9·30	8·073
,, (Ditto reduced)	Ditto ditto March 2, 1859	8·35	7·249
,, (Philp's propeller)	Ditto ditto July 1, ,,	9·20	7·989
,, (Ditto ditto)	Ditto ditto Sept. 27, ,,	8·77	7·612
,, (Hirsch's propeller)	Ditto ditto Oct. 13, ,,	9·23	8·015
,, (Ditto ditto)	Ditto ditto Feb. 24, ,,	7·88	6·843

TABLE (*continued*).

Horse-power.		Ratio of nominal to indicated horse-power.	Ratio of indicated to nominal horse-power.	Ratio of grate-surface to indicated horse power.	Ratio of tube-surface to indicated horse-power.	Ratio of other heating surface to indicated horse-power.	Ratio of total heating surface to indicated horse-power.	Ratio of heating surface to grate-surface.	Ratio of other heating surface to tube-surface.	Coal consumed per hour per indicated horse-power.	Water evaporated per hour per indicated horse-power.	Water evaporated per hour per lb. of fuel.
Indicated.	Nominal.											
2754·64	800	·291	3·443	·198	...	...	5·240	26·47				
1429	800	·560	1·786	·381	...	...	10·077	26·47				
3182·6	800	·251	3·978	·171	...	...	4·525	26·47				
3617	1000	·276	3·617	·188	*	...	5·021	26·71				
3992	1000	·251	3·992	·170	...	...	4·549	26·71				
293·9	80	·272	3·674	·136	4·627	·476	5·103	37·50	·103			
299·5	80	·267	3·744	·133	4·541	·467	5·008	37 50	·103			
303·6	80	·264	3·791	·132	4·479	·461	4·941	37·50	·103			
299·8	80	·267	3·748	·133	4·533	·467	5·003	37·50	·103			
1166	350	·300	3·331	·212	4·819	1·089	5·909	27·89	·226			
1090·88	350	·321	3·117	·226	5·152	1·165	6·316	27·89	·226			
1089·60	350	·321	3·113	·227	5·157	1·165	6·323	27·89	·226			
1266·9	350	·276	3·619	·195	4·436	1·002	5·439	27·89	·226			
1174·88	350	·298	3·357	·210	4·783	1·081	5 864	27·89	·226			
1049·68	350	·334	2·999	·236	5 367	1·209	6·579	27·89	·226			
1195	600	·502	1·992	·326	6·587	1·889	8·477	25·97	·286			
					5·482	1·572	7·054	25·97	·286			
1436	600	·417	2·393	·271								
258	300	1·162	·860	·868								
408·6	300	·734	1·362	·548								
480	300	·625	1·600	·466	...	...	8·981					
453·124	220	·486	2·059	·300	none	5·442	5·442	18·13				
394	220	·558	1·791	·345	none	6·259	6·259	18·13				
1122	540	·481	2·078	·267	3·863	5·117	8·981	33·59	1·324			
954	540	·566	1·767	·314	4·544	6·018	10·563	33·59	1·324			
261·6	80	·306	3·270	·229	4·556	·906	5·463	33·82	·198			
317·4	80	·252	3·968	·189	3·755	·746	4·502	23·82	·198			
283	60	·212	4·717	·120	*	...	3·943	32·631				
240·62	60	·250	4·010	·142	...	...	4·638	32·631				
216·50	60	·277	3·608	·158	...	...	5·155	32·631				
222·67	60	·269	3·711	·153	...	...	5·012	32·631				
241·48	60	·248	4·025	·142	...	...	4·621	32·631				
196·82	60	·305	3·280	·174	...	...	5·620	32·631				
223·90	60	·268	3·731	·153	...	...	4·984	32·631				
220·13	60	·273	3·669	·155	...	...	5·069	32·631				
211·62	60	·283	3·527	·166	...	...	5·274	32·631				
240 60	60	·249	4·010	·142	...	...	4·638	32·631				
199·68	60	·300	3·328	·171	...	...	5·589	32·631				

* Particulars of the tube-surface were not furnished by the manufacturers of the engines.

TABLE (*continued*).

Name of vessel.	Place and nature of performance.	Speed.	
		Statute miles.	Knots.
MERCHANT VESSELS.			
Anglia (paddle)	Mean of six special trips on ordinary service between Holyhead and Kingstown, 29th September to 3rd October, 1854	14·93	12·97
Cambria (paddle)	Ditto ditto, 22nd to 26th May, 1856	14·07	12·21
Scotia (paddle)	Ditto ditto, 17th to 21st May, 1855	15·68	13·61
Telegraph (paddle)	Ditto of two trips, 29th May, 1855	15·24	13·23
Atrato (paddle)	On trial, Stokes Bay, March 13, 1854	15·86	13·771
,,	Ditto ditto January 22, 1857	...	...
,,	Ditto ditto March 4, 1857	...	...
Mersey (paddle)	Ditto, Stokes Bay, April 21, 1859	15·31	13·288
Paramatta (paddle)	Ditto, Stokes Bay, June 7, 1859	16·08	13·951
Shannon (paddle)	Ditto, Frith of Clyde, July 8, 1859	16·01	13·898
,,	Ditto, Stokes Bay, August 1, ,,	16·60	14·412
Tasmanian (screw)	Ditto, Stokes Bay, June 15, 1858	16·42	14·25
Oneida (screw)	Ditto, Stokes Bay, July 27, 1858	14·86	12·9
Callao (paddle)	Ditto, Glasgow to Liverpool, Oct. 22, 1858.	14·86	12·90
Lima (paddle)	Ditto, Liverpool to Kingstown, May 20, 1859	13·82	12·00
Valparaiso (paddle)	Ditto in the Clyde, Sept. 16, 1859	13·28	11·53
Bogota (paddle)	Ditto, Glasgow to Liverpool, Sept. 22, 1859.	14·40	12·50
San Carlos (screw)	Ditto in the Mersey, February 20, 1860	13·54	11·75
Guayaquil (screw)	Ditto. Glasgow to Liverpool, March 22, 1860	13·82	12·00
Undine (screw)	Measured mile, Greenhithe, July 6, 1858.	10·67	9·26
,,	Holyhead to Mull of Cantyre, July 29, 30, 1858	11·49	9·97
,,	Run in Lochs Ness and Lochy, Oct. 26, 27, 28, 1858	9·48	8·23
Erminia (screw)	Ditto in Stokes Bay, Oct. 12, 1858	6·87	5·96
John Penn (paddle)	Ditto, Lower Hope, Feb. 6, 1860	17·63	15·3

TABLE (*continued*).

Horse-power.		Ratio of nominal to indicated horse-power.	Ratio of indicated to nominal horse-power.	Ratio of grate-surface to indicated horse-power.	Ratio of tube-surface to indicated horse-power.	Ratio of other heating surface to indicated horse-power.	Ratio of total heating surface to indicated horse-power.	Ratio of heating surface to grate-surface.	Ratio of other heating surface to tube-surface.	Coal consumed per hour per indicated horse-power.	Water evaporated per hour per indicated horse-power.	Water evaporated per hour per lb. of fuel.
Indicated.	Nominal.											
										lbs.		
816·07	330·52	·405	2·469	·196	4·769	·558	5·327	27·17	·117	6·837		
995·35	392·10	·394	2·538	·166	5·544	·452	5·996	36·17	·081	5·787		
934·18	379·92	·407	2·458	·199	4·943	·627	5·571	27·98	·127	6·679		
1165·98	448	·384	2·603	·142	6·332	1·377	7·368	51·68	·164	6·691		
...	800	...	...	...	...	...	...	47·91	1·106			
...	800	...	...	...	...	...	...	47·91	1·106			
2396·44	800	·334	2·995	·217	3·346	3·703	7·049	47·91	1·106	3·739		
1088	250	·230	4·352	·163	4·044	·925	4·960	30·39	·228			
2940	764	·260	3·848	·202	4·998	·872	5·871	29·05	·174			
2928·5	774	·264	3·783	·193	5·042	1·259	6·302	32·55	·249			
3790	774	·204	4·897	·149	3·896	·973	4·869	32·55	·249			
2800	550	·196	5·091	·182	3·768	·537	4·306	23·641	·142	3·000		
1912	450	·235	4·249	·222	4·789	·795	5·584	25·17	·166	3·514		
1050	320	·305	3·281	·133	1·904	1·142	3·047	22·85	·600	2·133		
1160	320	·276	3·625	·117	1·465	1·293	2·758	23·53	...	2·615		
800	320	·400	2·500	·162	none	...	3·000	18·46	...	3·080		
1100	320	·291	3·438	·127	1·818	1·091	2 909	22·85	·600	2·036		
500	120	·240	4·167	·152	none	...	4·400	28·94	...	2·352		
600	120	·200	5 000	·123	...	...	3·666	29·73	...	1·866		
157·09	50	·318	3·142	·287	4·697	1·311	6·009	20·90	·279			
158·77	50	·315	3·175	·284	4·648	1·297	5·945	20·90	·279			
160·84	50	·311	3·217	·281	4·588	1·281	5·869	20·90	·279			
54 59	30	·550	1·819	...	8·172	1·702	9·875	38·174	·208			
798	150	·188	5·320	·162	...	...	4·229					

APPENDIX V.—Letter from Mr. Archbold, Engineer-in-Chief, U. S. Navy.

Office of Engineer-in-Chief,
Washington, D.C., May 12th, 1860.

SIR,—I have the honour to transmit herewith, an abstract of the performance of the U. S. Steam-sloop 'Wyoming,' under steam alone, and under steam and sail, on the passage from Philadelphia to Valparaiso, Chili, collated from the logs of the engineer department of the ship.

I am unable to give you any account of her performances under sail alone, as in these logs no note of the sail is made when not under steam, and the ship's logs are not sent to the Navy Department until the end of the cruise. No trial of the ship was made in smooth water uninfluenced by sea from which any data of value can be obtained. We do not try our ships at the measured mile, the guarantees required of the contractors of the machinery being on performances at sea, and for an extended length of time. The results for each day, as shown by the abstracts, are not assumed to be strictly correct, as the data from which they are calculated are taken from the ordinary observations of the engine-room, subject to errors and inaccuracies unavoidable when the observers are so many, on duty for so short a time, and when attention is necessarily engrossed for the greater portion of the time in the care of the machinery. But as the errors are as likely to be on the one side of the truth as the other, the average and means will not be far from correct.

Indicator diagrams were not found in the logs for each day, which will account for the omissions in some of the columns, and there was but one set taken during each twenty-four hours. The horse-power for the day was calculated from these diagrams, correcting for the average revolutions for the day; and the horse-power for those days during which no diagrams were taken, is calculated from those taken on days when the circumstances of wind and sea were as nearly similar as could be found. The force of wind is expressed in our logs by numbers, as follows:—0, for calm; 1, light air; 2, light breeze; 3, gentle breeze; 4, moderate breeze; 5, fresh topgallant breeze; 6, strong single-reefed topsail breeze; 7, moderate gale, or double-reefed topsails; 8, fresh gale, or three-reefed topsails; 9, strong gale, or close-reefed topsails and reefed courses; 10, heavy gale, or close-reefed maintopsails and reefed trysails; 11, storm trysails, or storm staysails; 12, hurricane, or when no sail would stand.

In the column headed "cut-off," the figures indicate the distance in inches the steam followed the piston.

The apparent discrepancy in the consumption of coal for the days between October 25 and 31 inclusive, and some of the columns of which the coal was the dividend, arises from the distilling apparatus having been in use, making fresh water for ship's use; the amount of fuel due to the water freshened having been deducted before dividing. It should be remarked, in justice to our system of surface condensing, that the vacuum shown by these abstracts is not so good by from 10 to 12 per cent. as has been obtained by the same engines on former occasions, or by condensers of the same class in other ships.

I trust you will find in the abstracts everything necessary to the object you have in view, and you may depend upon the truthfulness of the result as nearly as they could be obtained from the data we have before us. We have, in common with your Association, felt the want of systematized authentic information upon steam-ship performance, and should feel obliged by the receipt of any facts in relation to any of your modern vessels of war, which the plan you have organized has developed; in return for which we shall be happy to render further service if desired.

I have the honour to be, Sir,
Your obedient Servant,
Samuel Archbold,
Engineer-in-Chief, U.S. Navy.

Vice-Admiral C. R. Moorsom,
Chairman of the Committee on Steam-ship Performance, British Association.

Description and dimensions of the Hull, Engines, and Boilers of United States Sloop 'Wyoming.'

HULL.

	ft.	in.
Length over all	232	9
Length on spar deck	209	9
Length between perpendiculars	198	6
Length of keel from back part of forward stern post	158	0
Width of beam, moulded	32	2
Width of beam, extreme	33	0
Depth of hold	15	10
Space allotted to machinery	50	8
Draft of water (loaded) forward	13	3
Draft of water (loaded) aft	13	4
Area of immersed midship section	sq. 391	0
	tons.	
Displacement	1475	
Tonnage	997	
Mean angle of entrance	17°	30′
Mean angle of exit	15°	30′

ENGINES.

Two in number, horizontal, with double piston rods, and direct-acting; slide valves, and independent cut-off valves, and situated 76 feet 6 inches from screw. One surface condenser common to both engines, containing 3000 square feet of tube-surface.

	ft.	in.
Cylinder, not jacketed, diameter	4	2
Cylinder, stroke of piston	2	6

The air-pump (one to each engine) is worked directly from the cross-head, and consequently has the same stroke as the steam-piston. Its piston is a barrel plunger, packed by a gland in the centre of the pump. The foot valves of vulcanized rubber are situated beneath the plunger, and the deliveries above it.

		ft.	in.
Capacity of air-pump, one revolution	cubic	3	3
Area of foot valves, one end	sq.	179	5
Area of delivery valves, one end	sq.	270	0

There is also a cold water circulating pump to each engine of the same dimensions as the air-pump.

BOILERS.

Three boilers, with vertical water space tubes over the furnaces. Shells of iron, tubes of brass, placed two on one side of the ship (of which one consists of a single furnace and is used as an auxiliary or "donkey," and to supply the deficiency of fresh water caused by leakage, &c.) and one on the other side, facing each other, with a fire-room fore and aft between them.

		ft.	in.
Length of boiler		24	9
Breadth, including fire-room		29	0
Depth, exclusive of steam drum		10	2
Depth, inclusive of steam drum 10 ft. diameter		14	2
Fire-room, length		24	9
Fire-room, width		8	6
Heating surface in all boilers	sq.	7890	0
Tubes, in length		2	7¼
Tubes, internal diameter		0	2
Tubes, in number		4280	

FURNACES.

		ft.	in.
Breadth, except "donkey," which is 2 ft. 6 in.		3	0
Length		5	10
Area of all grates	sq.	242	0
Smoke-pipe, one telescopic, height when up (above grate)		52	0
Diameter		6	10
Area	sq.	36	7
Least area between tubes in all boilers	sq.	35	65

	tons.
Weight of boilers	74·75
Weight of water in boilers	41·37

	ft.	in.
Cubic contents of water space	1484	0
Cubic contents of steam space	1318	0
Contents of combustion chamber, each furnace	6183	0
Distance of fire-bars from top of furnace	2	0
Distance of fire-bars from ash-pit	1	4

PROPELLER, one true screw of brass.

		ft.	in.
Number of blades		4	0
Diameter of screw		12	13
Diameter of boss		1	9½
Pitch		19	0
Length		2	6
Projected area at right angles of axis	sq.	41·36	

Total weight of machinery, spars, &c., with water in boilers ...... tons 227

Carries 235 tons Anthracite coal.

The coal used was Blackheath Anthracite of the hardest variety. Its analysis, as given by Professor Johnson, is—carbon, 92·12; water, hydrogen, and volatile matter, 4·83; ashes, &c., 3·05. Specific gravity 1·477.

es Steam Sloop ‘W [*To face p.* 216.

	Temperature of hot well.	Temperature of sea water.	Slip of screw.	Furnaces in work power.	Evaporation. Water per lb. of coal.	Water per lb. of combustible.	Steam to produce one horse-power.
					lbs.	lbs.	lbs.
ble.	81°	75°	21·5	135			
2	87	75	30·4	,64			
7	84	74	29·83	,'			
	86	79	32·3	,6	9·6	10·82	49
7	88	79	29·4	,0	9·5	11·34	54·4
	88	79	32·4	,3	9·27	11	35·2
5	93	79	26·4	,3	8·55	11·5	34·9
3	93	82	26	,2	9·03	11·9	33
2	92	81	35·3	,6	8·25	9·19	32·7
5	85	73	33·8	69	7·26	9·2	45·5
	89	72	33·5	78	5·29	6·22	24·2
5	87	60	24·6	,6			
7	77	58	20·4	,85	6·8	8·3	29·2
5	73	55	14·1	,48			
7	75	55	26·7	,68	6·37	7·15	32
	75	52	23·5	,3	6·62	8·7	36·8
4	98	51	27·4	1(7	5·96	7·33	23·4
4	86	69·4	28·09	..24	7·71	9·39	35·86

ates Steam Sloop ‘V

Boi

			cub. ft.	ft. in.
26	2	Tubular super-heated to 400°	480	2 0
14·25	"		"	"
16½	4	Tubular	800	2 0
8·25	"	"	"	"
26	2	Tubular	300 F. 200	2 0 3 0
13·83	"	"		
......	4	Tubular	800	2 0
8·82	"	"	"	"

Engines.

p-	Evaporation of water during trial.	Indicated horse-power.	Revolutions of the propeller during trial.	Measured speed per hour with tide.	Measured speed per hour against tide.	Average speed of runs according to Admiralty practice.
:s.	lbs.			knots.	knots.	knots.
5	270,000	1160	24	13·50	12·25	12·00
)	......	......	Total 632·158	......	......	8 25
	......	1300	......	......	......	13
)	......	......	......	......	......	7·66
)	Not ascertained.	1100	23	(Dist.	180)	12·5
)	......	......	Total 677·660	......	......	8·0
	......	1300	......	......	......	12¾
5	......	......	566·799	......	......	8·0

Total weight of ngine.	Piston.		Temperature of feed water.	Nominal horse-power.	Pressure of steam at same instant in boiler, and before throttle-valve.	Vacuum in condenser.	Pressure in cylinder.	Pressure from vacuum.
	Speed in feet per minute.	No. of revolutions per minute.						
tons.								
220	240	24	90°	320	24	28	21	32
,,	153·80	15·38	...	,,	...	...	...	...
220	270	22½	...	400	16	...	12½	24
,,	170·16	14·18	...	,,	,,	...	...	...
220	230	23	90	320	{26	27	23	33
,,	146	14·6	...	,,	24}	...	...	...
220	...	...	...	400	...	...	12½	24
,,	155	12·90	...	,,	...	...	...	...

d on :ty-	Consumption of coal per hour.	Remarks.

Interim Report on the Gauging of Water by Triangular Notches.

2 Donegal Square West, Belfast,
23rd June, 1860.

Dear Sir,—With reference to the experiments on the gauging of water by its flow in triangular notches, authorized by the General Committee at Aberdeen, I have to report, for the information of the Association, that, as they have to be carried on in the open air in a field adjacent to a waterfall at several miles distance from home, and as they require the formation of ponds and the construction of measuring tanks, sluices, &c., and involve careful and repeated observations continued often through whole days, fine summer weather free from both rain and wind is almost quite essential, and winter weather is peculiarly unsuitable. For these reasons, and on account of my duties at Queen's College here, I could not enter on the construction of the experimental works until the close of the College Session, which occurred only on the 9th inst. I have now, however, got the principal parts of the works constructed, and have got preliminary trials made, but I have found it impossible to have the final experiments ready for the very early Meeting of the Association which occurs in the present year. For these experiments a grant of £10 was placed at my disposal; and in order to meet the costs already incurred, of which some, from the nature of the case, are at present uncertain, I now apply to the Treasurer for the whole amount of the grant, for which I shall account at next year's Meeting, giving at that meeting my report on the experiments now in progress.

I am, dear Sir, yours faithfully,
James Thomson.

To John Phillips, Esq., LL.D., F.R.S.,
Assistant General Secretary, British Association.

List of the British Marine Invertebrate Fauna.

[For the Dredging Committee of the British Association.]

NOTICE.

The following lists have been prepared in conformity with the desire of the Committee of the Natural History Section of the British Association for the Advancement of Science, which, at my suggestion, recommended the appointment of a general Dredging Committee, with a liberal grant of money for the carrying out of its objects.

It is intended to place these lists in the hands of the local Dredging Committees and naturalists engaged in researches in the most important districts of the coasts of Great Britain and Ireland, with a request that they may be returned, with notes on the conditions under which each species of the particular district has been found, and memoranda of such additional species as may be obtained. By this means it is hoped to collect local lists of great interest, and materials for a more complete catalogue of the Invertebrate Fauna of the British Seas. In the preparation of the present lists, I have been assisted by Dr. Baird and Mr. S. Woodward and other members of the Dredging Committee. The catalogue of Mollusca is taken from the work of Messrs. Forbes and Hanley; that of Crustacea has been obligingly furnished by Mr. Spence Bate; of Radiata by Mr. Stuart, of the Royal College of Surgeons; of Sponges by Dr. Bowerbank; of Rhizopoda by Messrs. Rupert Jones and Parker; and to Dr. J. E. Gray I am indebted for permission to extract the list of Annelida from an unpublished work by the late Dr. Johnston, of Berwick-upon-Tweed.

ROBERT McANDREW.

Isleworth House, Feb. 10, 1860.

⁂ The nomenclature and arrangement are taken (with a few slight modifications) from the "British Mollusca" of Messrs. Forbes and Hanley.

††† The species marked with an asterisk have been recorded as British since the time when Mr. Barrett prepared the following list.

CEPHALOPODA.

- Octopus, *Cuvier*.
  - vulgaris, *Lam.*
- Eledone, *Leach*.
  - octopodia, *Penn.*
- Rossia, *Owen*.
  - Owenii, *Ball*.
  - macrosoma, *Delle Chiaje*.
- Sepiola, *Leach*.
  - Rondeletii, *Leach*.
  - Atlantica, *D'Orbigny*.
- Ommastrephes, *D'Orbigny*.
  - sagittatus, *Lam.*
  - todarus, *Delle Chiaje*.
  - Eblanæ, *Ball*.
- Loligo, *Lamarck*.
  - vulgaris, *Lam.*? (Forbesi, *Stp.*).
  - media, *Linn.*
  - marmoræ, *Verany* (media, *var.*).
- Sepia, *Linnæus*.
  - officinalis, *Linn.*
  - elegans, *Bl.*
  - biserialis, *De Montfort*.

GASTEROPODA.

Order PROSOBRANCHIATA.

- Murex, *Linnæus*.
  - erinaceus, *Linn.*
  - corallinus, *Scacchi*.
- Trophon, *Montfort*.
  - clathratus, *Linn.*
  - muricatus, *Mont.*
  - Barvicensis, *Johnston*.
- Fusus, *Lamarck*.
  - gracilis, *Da Costa*.
  - propinquus, *Alder*.
  - Berniciensis, *King*.
  - Dalei, *J. Sowerby*.
  - fusiformis, *Broderip*.
  - antiquus, *Linn.*
  - Norvegicus, *Chemn.*
  - Turtoni, *Bean*.
- Buccinum, *Linnæus*.
  - undatum, *Linn.*
  - Humphresianum, *Bennett*.
- Nassa, *Lamarck*.
  - reticulata, *Linn.*
  - pygmæa, *Lamarck*.
  - incrassata, *Müller*.
- Purpura, *Lamarck*.
  - lapillus, *Linn.*
- Columbella, *Lam.*
  - nana, *Lovén*.
- Mangelia, *Leach*.
  - attenuata, *Mont.*
  - costata, *Pennant*.
  - brachystoma, *Philippi*.
  - *Ginnaniana, *Philippi*.
  - gracilis, *Mont.*
  - Leufroyi, *Michaud*.
  - linearis, *Mont.*
  - nebula, *Mont.*
  - purpurea, *Mont.*
  - rufa, *Mont.*
  - septangularis, *Mont.*
  - striolata, *Scacchi*.
  - teres, *Forbes*.
  - Trevelliana, *Turton*.
  - turricula, *Mont.*
- Lachesis, *Risso*.
  - minima, *Mont.*
- Marginella, *Lamarck*.
  - lævis, *Donovan*.
- Ovula, *Lamarck*.
  - patula, *Pennant*.
  - ? acuminata, *Bruguière*.
- Cypræa, *Linnæus*.
  - Europæa, *Mont.*
- Natica, *Lamarck*.
  - monilifera, *Lamarck*.
  - nitida, *Donovan*.
  - sordida, *Philippi*.
  - Montagui, *Forbes*.
  - helicoides, *Johnston*.
  - pusilla, *Say*.
  - Kingii, *Forbes*.
- Lamellaria, *Montagu*.
  - perspicua, *Linn.*
  - tentaculata, *Mont.*
- Velutina, *Fleming*.
  - flexilis, *Mont.*
  - lævigata, Linn.
- ? Otina, *Gray*.
  - otis, *Turton*.
- Trichotropis, *Broderip*.
  - borealis, *Brod.*
- *Triton, *Lamarck*.
  - cutaceus, *Lam.*
  - nodiferus, *Lam.*
- Cerithiopsis, *Forbes & Hanley*.
  - *Naiadis, *Woodw.*
  - *nivea, *Jeffr.*
  - *pulchella, *Jeffr.*
  - tubercularis, *Mont.*
- Odostomia, *Fleming*.
  - acuta, *Jeffreys*.
  - alba, *Jeffreys*.
  - conoidea, *Brocchi*.
  - conspicua, *Alder*.
  - cylindrica, *Alder*.
  - decussata, *Mont.*
  - dolioliformis, *Jeffreys*.
  - dubia, *Jeffreys*.
  - eulimoides, *Hanley*.
  - excavata, *Philippi*.
  - glabrata, *Mühlfeldt*.
  - Gulsonæ, *Clark*.
  - insculpta, *Mont.*
  - interstincta, *Mont.*
  - minuta, *Jeffreys*.
  - nitida, *Alder*.
  - obliqua, *Alder*.
  - pallida, *Mont.*
  - plicata, *Mont.*
  - rissoides, *Hanley*.
  - spiralis, *Mont.*
  - striolata, *Alder*.
  - truncatula, *Jeffreys*.
  - unidentata, *Mont.*
  - Warrenii, *Thompson*.
  - *Lukisii, *Jeffr.*
- Eulimella, *Forbes*.
  - acicula, *Philippi*.
  - affinis, *Philippi*.
  - clavula, *Lovén*.
  - Scillæ, *Scacchi*.
- Chemnitzia, *D'Orbigny*.
  - clathrata, *Jeffreys*.
  - elegantissima, *Mont.*
  - fenestrata, *Jeffreys*.

formosa, *Jeffreys.*
fulvocincta, *Thomps.*
indistincta, *Mont.*
rufa, *Philippi.*
rufescens, *Forbes.*
scalaris, *Philippi.*
eximia, *Jeffreys.*
Eulima, *Risso.*
polita, *Linn.*
distorta, *Deshayes.*
subulata, *Donovan.*
bilineata, *Alder.*
*stenostoma, *Hanley.*
Stylina, *Fleming.*
Turtoni, *Broderip.*
Cerithium, *Bruguière.*
metula, *Lovén.*
reticulatum, *Da Costa.*
adversum, *Mont.*
*niveum, *Jeffr.*
Aporrhaïs, *Aldrovandus.*
pes-carbonis, *Brongniart.*
pes-pelecani, *Linn.*
Turritella, *Lamarck.*
communis, *Risso.*
Aclis, *Lovén.*
ascaris, *Turton.*
supranitida, *S. Wood.*
? unica, *Mont.*
nitidissima, *Mont.*
Cæcum, *Fleming.*
trachea, *Mont.*
glabrum, *Mont.*
Scalaria, *Lamarck.*
Turtoni, *Turton.*
communis, *Lamarck.*
clathratula, *Mont.*
Grœnlandica, *Chemnitz.*
Trevelyana, *Leach.*
Skenea, *Fleming.*
? costulata, *Müller.*
? lævis, *Philippi.*
planorbis, *Fabr.*
? nitidissima, *Adams.*
? rota, *Forbes.*
Truncatella, *Risso.*
Montagui, *Lowe.*
Jeffreysia, *Alder.*
opalina, *Jeffreys.*
diaphana, *Alder.*
globularis, *Jeffreys.*
Rissoa, *Frémenville.*
*Alderi, *Jeffr.*
abyssicola, *Forbes.*
anatina, *Drap.*
Beanii, *Hanley.*
calathus, *Forbes.*
cingillus, *Mont.*
costata, *Adams.*
costulata, *Risso.*
crenulata, *Michaud.*
fulgida, *Adams.*
inconspicua, *Alder.*
labiosa, *Mont.*
lactea, *Michaud.*
littorea, *Delle Chiaje.*
muriatica, *Lam.*
parva, *Da Costa.*
proxima, *Alder.*
pulcherrima, *Jeffreys.*
punctura, *Mont.*
rubra, *Adams.*
rufilabrum, *Alder.*
sculpta, *Philippi.*
semistriata, *Mont.*
soluta, *Philippi.*
striata, *Mont.*
striatula, *Mont.*
ulvæ, *Pennant.*
ventrosa, *Mont.*
vitrea, *Mont.*
Zetlandica, *Mont.*
Assiminea, *Leach.*
Grayana, *Leach.*
Lacuna, *Turton.*
crassior, *Mont.*
vincta, *Mont.*
puteolus, *Turton.*
pallidula, *Da Costa.*
Litorina, *Férussac.*
fabalis, *Turton.*
litoralis, *Linn.*
litorea, *Linn.*
neritoides, *Linn.*
tenebrosa, *Mont.*
palliata, *Say.*
patula, *Jeffreys.*
rudis, *Donovan.*
saxatilis, *Johnston.*
Adeorbis, *S. Wood.*
subcarinata, *Mont.*
divisa, *Fleming.*
Trochus, *Linn.*
alabastrum, *Beck.*
cinerarius, *Linn.*
conulus, *Linn.*
exiguus, *Pulteney.*
granulatus, *Born.*
crassus, *Pulteney* (lineatus, *Da Costa*).
magus, *Linn.*
millegranus, *Philippi.*
Montagui, *Gray.*
striatus, *Linn.*
tumidus, *Mont.*
umbilicatus, *Mont.*
lineatus, *Da Costa.*
zizyphinus, *Linn.*
Margarita, *Leach.*
undulata, *Sowerby.*
helicina, *Fabr.*
pusilla, *Jeffreys.*
Cutleriana, *Clark.*
Phasianella, *Lamarck.*
pullus, *Linn.*
Ianthina, *Lamarck.*
exigua, *Lamarck.*
communis, *Lamarck.*
pallida, *Harvey.*
Scissurella, *D'Orbigny.*
crispata, *Fleming.*
Haliotis, *Linn.*
tuberculata, *Linn.*
Emarginula, *Lamarck.*
reticulata, *J. Sow.*
rosea, *Bell.*
crassa, *J. Sow.*
Puncturella, *Lowe.*
Noachina, *Linn.*
Fissurella, *Lamarck.*
reticulata, *Donovan.*
Pileopsis, *Lamarck.*
Hungaricus, *Linn.*
Calyptræa, *Lamarck.*
Sinensis, *Linn.*
Acmæa, *Eschscholtz.*
testudinalis, *Müller.*
virginea, *Müller.*
Patella, *Linnæus.*
vulgata, *Linn.*
athletica, *Bean.*
pellucida, *Linn.*
lævis, *Pennant.*
Pilidium, *Forbes.*
fulvum, *Müller.*
Propilidium, *Forbes* (Lepeta, *Gr.*).
ancyloide, *Forbes.*
Dentalium, *Linnæus.*
entale, *Linn.*
Tarentinum, *Lam.*
Chiton, *Linnæus.*
fascicularis, *Linn.*
discrepans, *Brown.*
Hanleyi, *Bean.*
ruber, *Linn.*
cinereus, *Linn.*
albus, *Linn.*
asellus, *Chemn.*
cancellatus, *Sow.*
lævis, *Pennant.*
marmoreus, *O. Fabr.*

Order OPISTHOBRANCHIATA.

Tornatella, *Lamarck.*
fasciata, *Linn.*
Bulla, *Lamarck.*
hydatis, *Linn.*
Cranchii, *Leach.*
Akera, *Müller.*
bullata, *Linn.*
Cylichna, *Lovén.*
cylindracea, *Pennant.*
conulus, *Desh.*
*Lajonkaireana, *Basterot.*
mamillata, *Philippi.*
nitidula, *Lovén.*
obtusa, *Mont.*
strigella, *Lovén.*

truncata, *Adams.*
umbilicata, *Mont.*
Amphisphyra, *Lovén.*
hyalina, *Turton.*
Scaphander, *Montfort.*
lignarius, *Linn.*
Bullæa, *Lamarck.*
aperta, *Linn.*
quadrata, *S. Wood.*
scabra, *Müller.*
catena, *Mont.*
punctata, *Clark.*
pruinosa, *Clark.*
Aplysia, *Gmelin.*
hybrida, *Sow.*
Pleurobranchus, *Cuvier.*
plumula, *Mont.*
membranaceus, *Mont.*
Diphyllidia, *Cuvier.*
lineata, *Otto.*

Order NUDIBRANCHIATA.

(From the Monograph of Messrs. Alder and Hancock, 1856.)

Doris, *Linn.*
tuberculata, *Cuv.*
flammea, *A. & H.*
Zetlandica, *A. & H.*
millegrana, *A. & H.*
Johnstoni, *A. & H.*
planata, *A. & H.*
coccinea, *Forbes.*
repanda, *A. & H.*
aspera, *A. & H.*
proxima, *A. & H.*
muricata, *Müll.*
Ulidiana, *Thomps.*
diaphana, *A. & H.*
oblonga, *A. & H.*
bilamellata, *L.*
depressa, *A. & H.*
inconspicua, *A. & H.*
pusilla, *A. & H.*
sparsa, *A. & H.*
pilosa, *Müll.*
subquadrata, *A. & H.*
Goniodoris, *Forbes.*
nodosa, *Mont.*
castanea, *A. & H.*
Triopa, *Johnston.*
claviger, *Müll.*
Ægirus, *Lovén.*
punctilucens, *D'Orb.*
Thecacera, *Fleming.*
pennigera, *Mont.*
virescens, *A. & H.*
capitata, *A. & H.*
Polycera, *Cuvier.*
quadrilineata, *Müll.*
ocellata, *A. & H.*
Lessonii, *D'Orb.*
Ancula, *Lovén.*
cristata, *Alder.*
Idalia, *Leuckart.*
elegans, *Leuck.*
Leachii, *A. & H.*
aspersa, *A. & H.*
inæqualis, *Forbes.*
pulchella, *A. & H.*
quadricornis, *Mont.*
Tritonia, *Cuvier.*
Hombergii, *Cuv.*
alba, *A. & H.*
plebeia, *Johnston.*
lineata, *A. & H.*
Scyllæa, *Linn.*
pelagica, *Linn.*
Lomanotus, *Verany.*
marmoratus, *A. & H.*
flavidus, *A. & H.*
Dendronotus, *A. & H.*
arborescens, *Müll.*
Doto, *Oken.*
fragilis, *Forbes.*
pinnatifida, *Mont.*
coronata, *Müll.*
Æolis, *Cuvier.*
papillosa, *Linn.*
glauca, *A. & H.*
Alderi, *Cocks.*
coronata, *Forbes.*
Drummondi, *Thomps.*
punctata, *A. & H.*
elegans, *A. & H.*
rufibranchialis, *Johnst.*
lineata, *Lov.*
smaragdina, *A. & H.*
gracilis, *A. & H.*
pellucida, *A. & H.*
Landsburgii, *A. & H.*
alba, *A. & H.*
carnea, *A. & H.*
glaucoides, *A. & H.*
Peachii, *A. & H.*
nana, *A. & H.*
stipata, *A. & H.*
angulata, *A. & H.*
inornata, *A. & H.*
concinna, *A. & H.*
olivacea, *A. & H.*
aurantiaca, *A. & H.*
pustulata, *A. & H.*
Couchii, *Cocks.*
amœna, *A. & H.*
Northumbrica, *A. & H.*
arenicola, *Forbes.*
Glottensis, *A. & H.*
viridis, *Forbes.*
purpurascens, *Flem.*
cingulata, *A. & H.*
vittata, *A. & H.*
cærulea, *Mont.*
picta, *A. & H.*
tricolor, *Forbes.*
amethystina, *A. & H.*
Farrani, *A. & H.*
exigua, *A. & H.*
despecta, *Johnst.*
Embletonia, *A. & H.*
pulchra, *A. & H.*
minuta, *F. & G.*
pallida, *A. & H.*
Fiona, *A. & H.*
nobilis, *A. & H.*
Hermæa, *Lovén.*
bifida, *Mont.*
dendritica, *A. & H.*
Alderia, *Allman.*
modesta, *Lovén.*
Proctonotus, *A. & H.*
mucroniferus, *A. & H.*
Antiopa, *A. & H.*
cristata, *Del. Ch.*
hyalina, *A. & H.*

PTEROPODA.

Hyalea, *Lamarck.*
trispinosa, *Lesueur.*
Spirialis, *Eydoux & Souleyet.*
Flemingii, *Forbes.*
Jeffreysii, *Forbes.*
MacAndrei, *Forbes.*
Clio, *Müller.*
borealis, *Linn.*

LAMELLIBRANCHIATA.

Ostrea, *Linnæus.*
edulis, *Linn.*
Anomia, *Linnæus.*
aculeata, *Müller.*
ephippium, *Linn.*
striata, *Lovén.*
patelliformis, *Linn.*
Pecten, *O. F. Müller.*
*aratus, *Gmelin.*
Danicus, *Chemnitz.*
maximus, *Linn.*
niveus, *Macgillivray.*
opercularis, *Linn.*
pusio, *Pennant.*
similis, *Laskey.*
tigrinus, *Müller.*
varius, *Linn.*
striatus, *Müller.*
furtivus, *Lovén.*
Lima, *Bruguière.*
hians, *Gmelin.*
Loscombii, *Sowerby.*
subauriculata, *Mont.*

- Avicula, *Bruguière.*
  - Tarentina, *Lam.*
- Pinna, *Linnæus.*
  - pectinata, *Linn.*
- Mytilus, *Linnæus.*
  - edulis, *Linn.*
- Modiola, *Lamarck.*
  - barbata, *Linn.*
  - modiolus, *Linn.*
  - *ovalis, *G. B. Sby.*
  - phaseolina, *Philippi.*
  - tulipa, *Lam.*
- Crenella, *Brown.*
  - costulata, *Risso.*
  - decussata, *Mont.*
  - discors, *Linn.*
  - nigra, *Gray.*
  - marmorata, *Forbes.*
  - rhombea, *Berkeley.*
- Arca, *Linnæus.*
  - lactea, *Linn.*
  - *nodulosa, *Müller.*
  - raridentata, *S. Wood.*
  - tetragona, *Poli.*
- Pectunculus, *Lamarck.*
  - glycimeris, *Linn.*
- Nucula, *Lamarck.*
  - decussata, *Sow.*
  - nitida, *Sow.*
  - nucleus, *Linn.*
  - radiata, *Hanley.*
  - tenuis, *Mont.*
- Leda, *Schumacher.*
  - caudata, *Don.*
  - pygmæa, *Münster.*
- Cardium, *Linnæus.*
  - aculeatum, *Linn.*
  - echinatum, *Linn.*
  - edule, *Linn.*
  - fasciatum, *Mont.*
  - nodosum, *Turton.*
  - Norvegicum, *Speng.*
  - *papillosum, *Poli.*
  - pygmæum, *Don.*
  - rusticum, *Linn.*
  - Suecicum, *Reeve.*
- Lucina, *Bruguière.*
  - borealis, *Linn.*
  - divaricata, *Linn.*
  - ferruginosa, *Forbes.*
  - flexuosa, *Mont.*
  - leucoma, *Turton.*
  - spinifera, *Mont.*
- Diplodonta, *Bronn.*
  - rotundata, *Mont.*
- Kellia, *Turton.*
  - suborbicularis, *Mont.*
  - rubra, *Mont.*
- Turtonia, *Hanley.*
  - minuta, *O. Fabr.*
- Montacuta, *Turton.*
  - bidentata, *Mont.*
  - ferruginosa, *Mont.*
  - substriata, *Mont.*
- Lepton, *Turton.*
  - Clarkiæ, *Clark.*
  - nitidum, *Turton.*
  - squamosum, *Mont.*
  - *sulcatulum, *Jeffr.*
- Galeomma, *Turton.*
  - Turtoni, *Sow.*
- Cyprina, *Lamarck.*
  - Islandica, *Linn.*
- Circe, *Schumacher.*
  - minima, *Mont.*
- Astarte, *Sowerby.*
  - arctica, *Gray.*
  - compressa, *Mont.*
  - crebricostata, *Forbes.*
  - elliptica, *Brown.*
  - sulcata, *Da Costa.*
  - triangularis, *Mont.*
- Isocardia, *Lamarck.*
  - cor, *Linn.*
- Venus, *Linnæus.*
  - casina, *Linn.*
  - fasciata, *Don.*
  - ovata, *Pennant.*
  - striatula, *Don.*
  - verrucosa, *Linn.*
- Cytherea, *Lamarck.*
  - chione, *Linn.*
- Artemis, *Poli.*
  - exoleta, *Linn.*
  - lincta, *Pult.*
- Lucinopsis, *Forbes.*
  - undata, *Penn.*
- Tapes, *Mühlfeldt.*
  - aurea, *Gmelin.*
  - decussata, *Linn.*
  - pullastra, *Wood.*
  - virginea, *Linn.*
- Venerupis, *Lamarck.*
  - irus, *Linn.*
- Petricola, *Lamarck.*
  - lithophaga, *Retzius.*
- Mactra, *Linnæus.*
  - elliptica, *Brown.*
  - helvacea, *Chemnitz.*
  - solida, *Linn.*
  - stultorum, *Linn.*
  - subtruncata, *Da Costa.*
  - truncata, *Mont.*
- Lutraria, *Lamarck.*
  - elliptica, *Linn.*
  - oblonga, *Chemn.*
- Tellina, *Linnæus.*
  - balaustina, *Linn.*
  - crassa, *Penn.*
  - donacina, *Linn.*
  - fabula, *Gronov.*
  - incarnata, *Linn.*
  - proxima, *Brown.*
  - pygmæa, *Philippi.*
  - solidula, *Pult.*
  - tenuis, *Da Costa.*
- Gastrana, *Sch.* (Diodonta, *F. & H.*).
  - fragilis, *Linn.*
- Psammobia, *Lamarck.*
  - costulata, *Turt.*
  - Ferroensis, *Chemn.*
  - tellinella, *Lam.*
  - vespertina, *Chemn.*
- Syndosmya, *Recluz.*
  - alba, *Wood.*
  - intermedia, *Thomps.*
  - prismatica, *Mont.*
  - tenuis, *Mont.*
- Scrobicularia, *Schumacher.*
  - piperata, *Gmelin.*
- Ervilia, *Turton.*
  - castanea, *Mont.*
- Donax, *Linnæus.*
  - anatinus, *Lam.*
  - politus, *Poli.*
- Solen, *Linnæus.*
  - ensis, *Linn.*
  - marginatus, *Pult.*
  - pellucidus, *Penn.*
  - siliqua, *Linn.*
- Ceratisolen, *Forbes.*
  - legumen, *Linn.*
- Solecurtus, *Blainville.*
  - candidus, *Renieri.*
  - coarctatus, *Gmelin.*
- Mya, *Linnæus.*
  - arenaria, *Linn.*
  - truncata, *Linn.*
- Corbula, *Bruguière.*
  - nucleus, *Lam.*
  - ovata, *Forbes.*
  - rosea, *Brown.*
- Sphenia, *Turton.*
  - Binghami, *Turton.*
- Neæra, *Gray.*
  - abbreviata, *Forbes.*
  - costellata, *Desh.*
  - cuspidata, *Olivi.*
- Poromya, *Forbes* (=Thetis, *Sby.*).
  - granulata, *Nyst.*
- Panopæa, *Menard de la Groye.*
  - Norvegica, *Speng.*
- Saxicava, *Bellevue.*
  - arctica, *Linn.*
  - *fragilis, *Nyst.*
  - rugosa, *Linn.*
- Cochlodesma, *Leach* (=Periploma, *Sch.*).
  - prætenue, *Pult.*
- Thracia, *Leach.*
  - convexa, *Wood.*
  - distorta, *Mont.*
  - phaseolina, *Lam.*
  - pubescens, *Pult.*
  - villosiuscula, *Macgill.*
- Lyonsia, *Turton.*
  - Norvegica, *Chemn.*
- Pandora, *Bruguière.*
  - obtusa, *Leach.*
  - rostrata, *Lam.*
- Gastrochæna, *Spengler.*
  - modiolina, *Lam.*
- Pholas, *Linnæus.*
  - candida, *Linn.*
  - crispata, *Linn.*
  - dactylus, *Linn.*

parva, *Penn.*
striata, *Linn.*
Pholadidea, *Turton.*
lamellata, *Turton.*
papyracea, *Solander.*
Xylophaga, *Turton.*
dorsalis, *Turton.*
Teredo, *Adanson.*
bipennata, *Turton.*
malleolus, *Turton.*
megotara, *Hanley.*
navalis, *Linn.*
Norvegica, *Speng.*
palmulata, *Lam.*

BRACHIOPODA.

Crania, *Retzius.*
anomala, *Müller.*
Rhynchonella, *Fischer.*
psittacea, *Chemn.*
Terebratula, *Bruguière.*
caput serpentis, *Linn.*
cranium, *Müller.*
capsula, *Jeffreys.*
Argiope, *Deslongchamps.*
cistellula, *Searles Wood.*
*decollata, *Chemn.*

TUNICATA.

Aplidium, *Savigny.*
ficus, *Linn.*
fallax, *Johnst.*
nutans, *Johnst.*
Sidnyum, *Savigny.*
turbinatum, *Savig.*
Polyclinum, *Savigny.*
aurantium, *M.-Edw.*
Amouroucium, *M.-Edw.*
proliferum, *M.-Edw.*
Nordmanni, *M.-Edw.*
Argus, *M.-Edw.*
Leptoclinum, *M.-Edw.*
maculosum, *M.-Edw.*
asperum, *M.-Edw.*
aureum, *M.-Edw.*
gelatinosum, *M.-Edw.*
Listerianum, *M.-Edw.*
punctatum, *Forbes.*
Distoma, *Gaertner.*
rubrum, *Savig.*
variolosum, *Gaertner.*
Botryllus, *Gaertner.*
Schlosseri, *Pallas.*
polycyclus, *Savig.*
gemmeus, *Savig.*
violaceus, *M.-Edw.*
smaragdus, *M.-Edw.*
virescens, *A. & H.*
bivittatus, *M.-Edw.*
rubens, *A. & H.*
castaneus, *A. & H.*
Botrylloides, *M.-Edw.*
Leachii, *Savig.*
ramulosa, *A. & H.*
albicans, *M.-Edw.*
radiata, *A. & H.*
rotifera, *M.-Edw.*
rubra, *M.-Edw.*
Clavelina, *Savigny.*
lepadiformis, *O. F. Müller.*
Perophora, *Wiegmann.*
Listeri, *Wiegm.*
Syntethys, *Forbes & Goodsir.*
Hebridicus, *F. & G.*
Ascidia, *Baster.*
intestinalis, *Linn.*
canina, *O. F. Müll.*
venosa, *O. F. Mull.*
mentula, *O. F. Müll.*
arachnoidea, *E. Forbes.*
scabra, *O. F. Müll.*
virginea, *O. F. Müll.*
parallelogramma, *O. F. Müll.*
prunum, *Müll.?*
orbicularis, *Müll.*
depressa, *A. & H.*
aspersa, *Müll.*
vitrea, *Van Beneden.*
conchilega, *O. F. Müll.*
echinata, *Linn.*
sordida, *A. & H.*
albida, *A. & H.*
elliptica, *A. & H.*
pellucida, *A. & H.*
Molgula, *E. Forbes.*
oculata, *E. Forbes.*
arenosa, *A. & H.*
Cynthia, *Savigny.*
microcosmus, *Savig.*
claudicans, *Savig.*
tuberosa, *Macgillivray.*
quadrangularis, *E. Forbes.*
informis, *E. Forbes.*
tessellata, *E. Forbes.*
limacina, *E. Forbes.*
morus, *E. Forbes.*
rustica, *Linn.*
grossularia, *Van Beneden.*
ampulla, *Brug.*
mamillaris, *Pallas.*
aggregata, *Rathke.*
coriacea, *A. & H.*
Pelonaia, *Forbes & Goodsir.*
corrugata, *Forbes & Hanl.*
glabra, *Forbes & Hanl.*
Salpa, *Chamisso.*
runcinata, *Cham.*
Appendicularia, *Chamisso*, sp.

CRUSTACEA.

BRACHYURA.

Stenorhynchus, *Lamarck.*
phalangium, *Pennant.*
tenuirostris, *Leach.*
Achæus, *Leach.*
Cranchii, *Leach.*
Inachus, *Fabr.*
Dorsettensis, *Penn.*
dorhynchus, *Leach.*
leptochirus, *Leach.*
Pisa, *Leach* (Arctopsis, *Lam.*).
tetraodon, *Leach.*
Gibbsii, *Leach* (lanata, *Lam.*)
Hyas, *Leach.*
araneus, *Fabr.*
coarctatus, *Leach.*
Maia, *Lam.*
squinado, *Herbst.*
Eurynome, *Leach.*
aspera, *Leach.*
Xantho, *Leach.*
florida, *Leach.*
rivulosa, *Edw.*
tuberculata, *Couch.*
Cancer, *Linn.*
pagurus, *Linn.*
Pilumnus, *Leach.*
hirtellus, *Leach.*
Pirimela, *Leach.*
denticulata, *Mont.*
Carcinus, *Leach.*
mænas, *Linn.*
Portumnus, *Leach.*
variegatus, *Leach* (latipes, *Penn.*).
Portunus, *Leach.*
puber, *Linn.*
corrugatus, *Leach.*
arcuatus, *Leach.*
depurator, *Leach.*
marmoreus, *Leach.*
holsatus, *Fabr.*
pusillus, *Leach.*
longipes, *Risso.*
plicatus, *Risso.*
carcinoides, *Kin.*
Polybius, *Leach.*
Henslowii, *Leach.*
Pinnotheres, *Latr.*
pisum, *Penn.*
veterum, *Bosc.*
Gonoplax, *Leach.*
angulata, *Leach.*
Planes, *Leach.*
Linnæana, *Leach.*
Ebalia, *Leach.*
Pennantii(tuberosa, *Penn.*).
Bryerii, *Leach* (tumefacta, *Mont.*).
Cranchii, *Leach.*
Atelecyclus, *Leach.*
heterodon, *Leach* (septemdentatus, *Mont.*).
Corystes, *Leach.*
Cassivelaunus, *Leach.*
Thia, *Leach.*
polita, *Leach.*

ANOMOURA.

- Dromia, *Edw.*
  - vulgaris, *Edw.*
- Lithodes, *Latr.*
  - Maia, *Leach.*
- Pagurus, *Fabr.*
  - Bernhardus, *Linn.*
  - Prideauxii, *Leach.*
  - Cuanensis, *Thompson.*
  - Ulidianus, *Thompson.*
  - Hyndmanni, *Thompson.*
  - lævis, *Thompson.*
  - Forbesii, *Bell.*
  - Thompsoni, *Bell.*
  - fasciatus, *Bell.*
  - Dillwynii, *Spence Bate.*
- Porcellana, *Lamarck.*
  - platycheles, *Penn.*
  - longicornis, *Penn.*
- Galathea, *Fabr.*
  - squamifera, *Leach.*
  - dispersa, *Spence Bate.*
  - strigosa, *Fabr.*
  - nexa, *Emb.*
  - Andrewsii, *Kinahan.*
- Munida, *Leach.*
  - Bamfica, *Penn.* (Rondeletii, *Bell*).

MACROURA.

- Scyllarus, *Fabr.*
  - arctus, *Linn.*
- Palinurus, *Fabr.*
  - Homarus, *Linn.*
- Callianassa, *Leach.*
  - subterranea, *Leach.*
- Gebia, *Leach.*
  - stellata, *Mont.*
  - deltura, *Leach.*
- Axius, *Leach.*
  - stirhynchus, *Leach.*
- Calocaris, *Bell.*
  - Macandreæ, *Bell.*
- Astacus, *Fabr.*
  - gammarus (*L.*) (marinus, *Fabr.*; vulgaris, *Edw.*).
- Nephrops, *Leach.*
  - Norvegicus, *Linn.*
- Crangon, *Fabr.*
  - vulgaris, *Fabr.*
  - fasciatus, *Risso.*
  - spinosus, *Leach.*
  - sculptus, *Bell.*
  - trispinosus, *Hailstone.*
  - bispinosus, *Westw.*, *Kinahan.*
  - Allmanni, *Kin.*
  - Pattersonii, *Kin.*
- Alpheus, *Fabr.*
  - ruber, *Edw.*
  - affinis, *Guise.*
- Autonomea, *Risso.*
  - Olivii, *Risso.*
- Nika, *Risso.*
  - edulis, *Risso.*
  - Couchii, *Bell.*
- Athanas, *Leach.*
  - nitescens, *Mont.*, *Leach.*
- Hippolyte, *Leach.*
  - spinus, *Sowerby.*
  - varians, *Leach.*
  - Cranchii, *Leach.*
  - Thompsoni, *Bell.*
  - Prideauxiana, *Leach.*
  - Gordoni, *Spence Bate.*
  - fascigera, *Gosse.*
  - Grayana, *Thompson.*
  - Mitchelli, *Thompson.*
  - Whitei, *Thompson.*
  - Yarrellii, *Thompson.*
  - Barleei, *Spence Bate.*
  - pandaliformis, *Bell.*
  - pusiola, *Kröyer.*
- Pandalus, *Leach.*
  - Jeffreysii, *Spence Bate*, *Kinahan.*
  - annulicornis, *Leach.*
  - leptorhynchus, *Kin.*
- Palæmon, *Fabr.*
  - serratus, *Penn.*
  - squilla, *Fabr.*
  - Leachii, *Bell.*
  - varians, *Leach.*
- Pasiphæa, *Savigny.*
  - sivado, *Risso.*
- Penæus, *Fabr.*
  - caramote, *Risso.*

STOMAPODA.

- Mysis, *Latr.*
  - chamæleon, *V. Thompson.*
  - vulgaris, *V. Thompson.*
  - Griffithsiæ, *Bell.*
  - Lamornæ, *Couch.*
  - productus, *Gosse.*
  - Oberon, *Couch.*
- Thysanopoda, *Edw.*
  - Couchii, *Bell.*
- Macromysis, *White* (Themisto, *Goodsir*, *Bell*).
  - longispinosus, *Goodsir.*
  - brevispinosus, *Goodsir.*
- Cynthilia, *White* (Cynthia, *V. Thomps.*, *Bell*).
  - Flemingii, *Goodsir.*
- Cuma, *Edwards.*
  - scorpioides, *Mont.*
  - unguiculata, *Spence Bate.*
- Vaunthomsonia, *Spence Bate.*
  - Edwardsii, *Kröyer.*
  - cristata, *Spence Bate.*
- Diastylis, *Say* (Alauna, *Goodsir*, *Bell*).
  - Rathkii, *Kr.* (rostrata, *Goodsir*, *Bell*).
- Eudora, *Spence Bate.*
  - truncatula, *Spence Bate.*
- Iphithoë, *Spence Bate* (Halia, *Spence Bate*, *White*).
  - trispinosa, *Goodsir.*
- Bodotria, *Goodsir.*
  - arenosa, *Goodsir.*
- Cyrianassa, *Spence Bate* (Venilia, *Spence Bate*, *White*).
  - gracilis, *Spence Bate.*
  - longicornis, *Spence Bate.*
- Squilla, *Fabr.*
  - Desmarestii, *Risso.*
  - mantis, *Rondelet.*
- Phyllosoma, *Leach.*
  - Cranchii, *Leach.*

AMPHIPODA NORMALIA.

- Talitrus, *Latr.*
  - locusta, *Auct.*
- Orchestia, *Leach.*
  - littorea, *Mont.*
  - Deshayesii, *Savig.*
  - Mediterranea, *Costa* (lævis, *S. Bate*; littorea, var., *White*).
- Allorchestes, *Dana.*
  - Nilssonii, *Kroyer* (Danai, *Spence Bate*).
  - imbricatus, *Spence Bate.*
- Nicea, *Nicolet* (Galanthis, *Spence Bate*).
  - Lubbockiana, *Spence Bate.*
- Montagua, *Spence Bate.*
  - monoculoides, *Montagu* (Typhis monoculoides, *White*, *Gosse*).
  - marina, *Spence Bate.*
  - Alderii, *Spence Bate.*
  - pollexiana, *Spence Bate.*
- Danaia, *Spence Bate.*
  - dubia, *Spence Bate.*
- Lysianassa, *M.-Edw.*
  - Costæ, *M.-Edw.*
  - Audouiniana, *Spence Bate.*
  - longicornis, *Lucas* (Chausica, *Sp. B.*, not *M.-E.*).
  - Atlantica, *Edw.* (marina, *Spence Bate*).
- Callisoma, *Hope* (Scopelocheirus, *Spence Bate*).
  - crenata, *Spence Bate.*
- Anonyx, *Kröyer.*
  - Edwardsii, *Kröyer.*

Edwardsii, *Kröyer*.
minutus, *Kröyer*.
Holbölli, *Kröyer*.
ampulla, *Kröyer*.
denticulatus, *Spence Bate*.
longipes, *Spence Bate*.
obesus, *Spence Bate*.
longicornis, *Spence Bate*.
Opis, *Kröyer*.
typica, *Kröyer*.
Ampelisca, *Kröyer* (Tetromatus, *Spence Bate*).
Gaimardii, *Kröyer* (typica, *Spence Bate*).
Belliana, *Spence Bate*.
Westwoodilla (Westwoodia, *Spence Bate*).
cæcula, *Spence Bate*.
hyalina, *Spence Bate*.
Monoculodes, *Stimpson*.
carinatus, *Spence Bate*.
Kröyera, *Spence Bate*.
arenaria, *Spence Bate*.
Phoxus, *Kröyer*.
simplex, *Sp. Bate* (Kröyeri, *Spence Bate*, not *Stimpson*).
plumosus, *Holböll*.
Holbölli, *Kröy*.
Sulcator, *Spence Bate*.
arenarius, *Spence Bate*.
Urothoë, *Dana*.
marinus, *Spence Bate* (Sulcator marinus).
Bairdii, *Spence Bate*.
medius, *Spence Bate*.
elegans, *Spence Bate*.
Grayia, *Spence Bate*.
imbricata, *Spence Bate*.
Liljeborgia, *Spence Bate*.
pallida, *Spence Bate*.
Phædra, *Spence Bate*.
antiqua, *Spence Bate*.
Kinahani, *Spence Bate*.
Isæa, *M.-Edwards*.
Montagui, *M.-Edw*.
Iphimedia, *Rathke*.
obesa, *Rathke*.
Eblanæ, *Spence Bate*.
Otus, *Spence Bate*.
carinatus, *Spence Bate*.
Acanthonotus, *Owen*.
testudo, *Montagu*.
Dexamine, *Leach*.
Loughrinii, *Spence Bate*.
spinosa, *Mont*.
Eusirus, *Kröyer*.
Edwardi, *Spence Bate*.
Helvetiæ, *Spence Bate*.
Atylus, *Leach*.
bispinosus, *Spence Bate*.
Huxleyanus, *Spence Bate*.
Gordonianus, *Spence Bate*.
Pherusa, *Leach*.
cirrus, *Spence Bate*.
fucicola, *Edw*.
Calliope, *Leach*.
Leachii, *Spence Bate*.
Lembos, *Spence Bate*.
Cambriensis, *Spence Bate*.
versiculatus, *Spence Bate*.
Websterii, *Spence Bate*.
Danmoniensis, *Spence Bate*.
Aöra, *Kroy*. (=Lalaria, *Nicolet*).
gracilis, *Spence Bate*.
Eurystheus, *Spence Bate*.
tridentatus, *Spence Bate*.
tuberculosus, *Spence Bate*.
Gammarella, *Spence Bate*.
brevicaudata, *M.-Edw*. (= G. orchestiformis, *Spence Bate*).
Crangonyx, *Spence Bate*.
subterranea, *Spence Bate*.
Amathia, *Rathke*.
Sabinii, *Leach*.
Gammarus, *Fabr*.
locusta, *Fabr*.
fluviatilis, *Rœsel*.
gracilis, *Rathke*.
camptolops, *Leach*.
marinus, *Leach*.
laminatus, *Johnston*.
longimanus, *Leach*.
palmatus, *Mont*. (inæquimanus, *Spence Bate*).
grossimanus, *Mont*.
maculatus, *Johnston*.
Bathyporeia, *Lindström* (Thersites, *Spence Bate*).
pilosa, *Lindström*.
pelagica, *Spence Bate*.
Robertsoni, *Spence Bate*.
Leucothoë, *Leach*, not *Kröyer*.
articulosa, *Mont*.
furina, *Savig*. (procera, *Sp. Bate*).
Pleonexes, *Spence Bate*.
gammaroides, *Spence Bate*.
Amphithoë, *Leach*.
rubricata, *Mont*.
littorina, *Spence Bate*.
? obtusata, *Leach*.
? dubia, *Johnston*.
Sunamphithoë, *Spence Bate*.
hamulus, *Spence Bate*.
conformata, *Spence Bate*.
Podocerus, *Leach*.
falcatus, *Mont*.
variegatus, *Leach*.
pulchellus, *Leach*.
Jassa ?, *Leach*.
pelagica, *Leach*.
Siphonœcetus, *Kröyer*.
Whitei, *Gosse*.
Erichthonius, *M.-Edw*.
difformis, *M.-Edw*.
Cyrtophium, *Dana*.
Darwinii, *Spence Bate*.
Corophium, *Latreille*.
longicorne, *Fabr*.
Chelura, *Philippi*.
terebrans, *Phil*.
Hyperia, *Latreille*.
Galba, *Mont*. (Latreillii, *Edw*. = Metœchus medusarum, *Latr*.).
oblivia, *Kröy*.

AMPHIPODA HYPERINA.

Læstrigonus, *Guérin*.
Fabricii, *M.-Edw*.
Phronima, *Latr*.
sedentaria, *Forsk*.
Typhis, *Risso*.
nolens, *Johnston*.

AMPHIPODA ABERRANTIA. (LÆMODIPODA of *Latreille*.)

Dulichia, *Kröyer*.
porrecta, *Spence Bate*.
falcata, *Spence Bate*.
Proto. *Leach*.
pedata, *Leach*.
Goodsirii, *Spence Bate*.
Protella, *Dana*.
longispina, *Kröyer*.
Caprella, *Lamarck*.
linearis, *Latr*.
Pennantii, *Leach*.
tuberculosa, *Goodsir*.
lobata, *Müller*.
acuminifera, *M.-Edw*.
Cyamus, *Latreille*.
ceti, *Linn*.
ovalis, *Roussel*.
gracilis, *Roussel*.
Thompsoni, *Gosse*.

ISOPODA ABERRANTIA. (ANISOPODA of *Dana*.)

Arcturus, *Latr*. (Astacilla, *Johnston*; Leachia, *Johnston*.)
longicornis, *Sow*.
intermedius, *Goodsir*.
gracilis, *Goodsir*.
Anthura, *Leach*.
gracilis, *Mont*.
cylindricus, *Mont*.
Tanais, *M.-Edw*.
Dulongii, *Aud*.
hirticaudatus, *Spence Bate*.

Apseudes, *Leach.*
  talpa, *Mont.*
Anceus, *Risso.*
  maxillaris, *Mont.*
  rapax, *M.-Edw.*
Praniza, *Leach.*
  ceruleata, *Mont.*
  fusca ?, *Johnston.*
  Edwardii, *Spence Bate.*
Liriope, *Kroyer.*
  balani, *Spence Bate.*
Ione, *Mont.*
  thoracica, *Mont.*
Bopyrus, *Latr.*
  squillarum, *Latr.*
  hippolytes, *Kröyer.*
Phryxus, *Rathke.*
  hippolytes, *Rathke.*
  paguri, *Rathke.*

ISOPODA (NORMALIA).

Munna, *Kröyer.*
  Kröyeri, *Goodsir.*
  Whiteana, *Spence Bate.*
Jæra, *Leach.*
  albifrons, *Leach.*
Oniscoda, *Latreille.*
  maculosa, *Leach.*
  Deshayesii, *Lucas.*
Limnoria, *Leach.*
  lignorum, *Rathke* (terebrans, *Leach*).
Idotea, *Fabr.*
  pelagica, *Leach.*
  tricuspidata, *Desm.*
  emarginata, *Fabr.*
  linearis, *Latr.*
  acuminata, *Leach.*
  appendiculata, *Risso.*
Ligia, *Fabr.*
  oceanica, *Linn.*
Sphæroma, *Latr.*
  serratum, *Fabr.*
  rugicauda, *Leach.*
  Hookeri, *Leach.*
Cymodocea, *Leach.*
  truncata, *Leach.*
  emarginata, *Leach.*
  Montagui, *Leach.*
  rubra, *Leach.*
  viridis, *Leach.*
Neræa, *Leach.*
  bidentata, *Adams.*
Campecopea, *Leach.*
  hirsuta, *Mont.*
  Cranchii, *Leach.*
Cirolana, *Leach.*
  Cranchii, *Leach.*
Eurydice, *Leach.*
  pulchra, *Leach.*
Æga, *Leach.*
  bicarinata, *Leach.*
  tridens, *Leach.*
Conilera, *Leach.*
  cylindracea, *Mont.*
Rocinela, *Leach.*
  Danmoniensis, *Leach.*
  monophthalma, *Johnston.*

ENTOMOSTRACA.

Order I. PHYLLOPODA.

Nebalia, *Leach.*
  bipes, *O. Fabr.*
Artemia, *Leach.*
  salina, *Linn.*

Order II. CLADOCERA.

Evadne, *Lovén.*
  Nordmanni, *Lovén.*

Order III. OSTRACODA.

Fam. I. **Cytheridæ.**

Cythere, *Müller.*
  flavida, *Müll.*
  reniformis, *Baird.*
  albo-maculata, *Baird.*
  alba, *Baird.*
  variabilis, *Baird.*
  aurantia, *Baird.*
  nigrescens, *Baird.*
  Minna, *Baird.*
  angustata, *Münster.*
  acuta, *Baird.*
  pellucida, *Baird.*
  impressa, *Baird.*
  quadridentata, *Baird.*
  convexa, *Baird.*
Cythereis, *Rupert Jones.*
  Whitei, *Baird.*
  Jonesii, *Baird.*
  antiquata, *Baird.*

Fam. II. **Cypridinidæ.**

Cypridina, *M.-Edw.*
  Macandrei, *Baird.*
  Brenda, *Baird.*
  Mariæ, *Baird.*
  interpuncta, *Baird.*

Order IV. COPEPODA.

Fam. I. **Cyclopidæ.**

Canthocamptus, *Westwood.*
  Strömii, *Baird.*
  furcatus, *Baird.*
  minuticornis, *Müll.*
Arpacticus, *M.-Edw.*
  chelifer, *Müll.*
  nobilis, *Baird.*
Alteutha, *Baird.*
  depressa, *Baird.*

Fam. II. **Diaptomidæ.**

Temora, *Baird.*
  Finmarchica, *Gunner.*
Calanus.
  euchæta, *Lubbock.*
  Anglicus, *Lubbock.*
Anomalocera, *Templeton.*
  Patersonii, *Templeton.*

Fam. III. **Cetochilidæ.**

Cetochilus, *Vauzème.*
  septentrionalis, *Goodsir.*
Pontella, *Dana.*
  Wollastoni, *Lubbock.*
Pontellina, *Dana.*
  brevicornis, *Lubbock.*
Peltidium, *Philippi.*
  purpureum ?, *Phil.*
Corycæus, *Dana.*
  Anglicus, *Lubbock.*

Fam. IV. **Monstrillidæ.**

Monstrilla, *Dana.*
  Anglica, *Lubbock.*

Species.	On what animals found.
Order V. SIPHONOSTOMA.	
Fam. I. **Caligidæ.**	
Caligus, *Müller.*	
diaphanus, *Nordm.*	various fishes.
rapax, *M.-Edw.*	various fishes.
Mülleri, *Leach*	various fishes.
centrodonti, *Baird*	sea bream.
minutus, *Otto*	holibut.
curtus, *Müll.*	ray.
Lepeophtheirus, *Nordmann.*	
Strömii, *Baird.*	on salmon.
pectoralis, *Müll.*	various fishes.

Species.	On what animals found.
Nordmanni, *M.-Edw.*	sun-fish.
hippoglossi, *Kröy.*	holibut.
obscurus, *Baird*	brill.
Thompsoni, *Baird*	turbot.
Chalimus, *Burmeister.*	
scombri, *Burm*	on mackerel.
Trebius, *Kröyer.*	
caudatus, *Kröy.*	on skate.
Fam. II. **Pandaridæ.**	
Dinemoura, *Latreille.*	
alata, *M.-Edw*	on shark.
lamnæ, *Johnst*	on shark.
Fam. III. **Cecropidæ.**	
Pandarus, *Leach.*	
bicolor, *Leach*	on shark.
Cecrops, *Leach.*	
Latreillei, *Leach*	on sun-fish.
Læmargus, *Kröyer.*	
muricatus, *Kroy.*	on sun-fish.
Fam. IV. **Anthosomidæ.**	
Anthosoma, *Leach.*	
Smithii, *Leach*	on shark.
Fam. V. **Ergasilidæ.**	
Nicothoë, *M.-Edwards.*	
astaci, *M.-Edw.*	on gills of lobster
Fam. VI. **Chondracanthidæ.**	
Chondracanthus, *De la Roche.*	
Zei, *De la Roche*	gills of dory.
Lernentoma, *De Blainville.*	
cornuta, *Mull.*	gills of sole.
asellina, *L.*	gills of gurnard.
lophii, *Johnst.*	pouches of angler.
Lerneopoda, *De Blainville.*	
elongata, *Grant*	shark.
Galei, *Kröy.*	shark.
salmonea, *L.*	salmon.
Fam. VII. **Anchorellidæ.**	
Anchorella, *Cuvier.*	
uncinata, *Müll.*	on the cod.
rugosa, *Kroy.*	on the cod.
Fam. VIII. **Lerneidæ.**	
Lernea, *L.*	
branchialis, *L.*	gills of cod.
Lerneonema, *M.-Edwards.*	
sprattæ, *Sby.*	on the sprat.
Bairdii, *Salter*	herring.
encrasicoli, *Turt.*	sprat.

CIRRIPEDIA.

Fam. I. **Balanidæ.**

Balanus (*Lister*).
tintinnabulum, *Linn.*
spongicola, *Brown.*
perforatus, *Bruguière.*
Amphitrite, *Darwin.*
eburneus, *Aug. Gould.*
improvisus, *Darwin.*
porcatus, *Da Costa.*
crenatus, *Bruguière.*
balanoides, *Linn.*
Hameri, *Ascanius.*
Acasta, *Leach.*
spongites, *Poli.*
Pyrgoma, *Leach.*
Anglicum, *G. B. Sby.*
Xenobalanus, *Steenstrup.*
globicipitis, *Steenstrup.*
Chthamalus, *Ranzani.*
stellatus, *Poli.*
Verruca, *Schumacher.*
Strömia, *O. Müller.*
Alcippe, *Hancock.*
lampas, *Hancock.*

Fam. II. **Lepadidæ.**

Lepas, *Linn.*
anatifera, *Linn.*
Hillii, *Leach.*
anserifera, *Linn.*
pectinata, *Spengler.*
fascicularis, *Ellis & Solander.*
Conchoderma, *Olfers.*
aurita, *Linn.*
virgata, *Spengler.*
Alepas, *Sander-Rang.*
parasita, *Sander-Rang.*
Anelasma, *Darwin.*
squalicola, *Lovén.*
Scalpellum, *Leach.*
vulgare, *Leach.*
Pollicipes, *Leach.*
cornucopia, *Leach.*

ARACHNIDA.

Order PODOSOMATA.

Fam. I. **Pycnogonidæ.**

Pycnogonum, *Fabricius.*
littorale, *Strom.*
Phoxichilus, *Latreille.*
spinosus, *Mont.*

Fam. II. **Nymphonidæ.**

Phoxichilidium, *M.-Edwards.*
coccineum, *Johnst.*
globosum.
olivaceum.
Pallene, *Johnston.*
brevirostris, *Johnst.*
Nymphon, *Fabricius.*
gracile, *Leach.*
grossipes, *O. Fabr.*
femoratum, *Leach.*
pictum.
giganteum, *Johnst.*

ANNELIDA.

⁂ The following list of British Marine Worms is copied, by favour of Dr. J. E. Gray, from an unpublished Catalogue by the late Dr. Johnston.

Order I. TURBELLARIA.

Fam. I. **Planoceridæ.**

Leptoplana, *Ehrenberg.*
subauriculata, *Johnston.*
tremellaris, *Müller.*
flexilis, *Dalyell.*
atomata, *Müller.*
ellipsis, *Dalyell.*
Eurylepta, *Ehrenberg.*
cornuta, *Müller.*
Dalyellii, *Johnston.*

sanguinolenta, *Quatrefages.*
vittata, *Montagu.*
Planocera, *Blainville.*
folium, *Grube.*

Fam. II. **Planariadæ.**

Planaria, *Müller.*
ulvæ, *Oersted.*
affinis, *Oersted.*
alba, *Dalyell.*
variegata, *Dalyell.*
? gracilis, *Dalyell.*
? falcata, *Dalyell.*

Fam. III. **Dalyellidæ.**

Typhloplana, *Ehrenberg.*
flustræ, *Dalyell.*
Convoluta, *Oersted.*
paradoxa, *Oersted.*

Doubtful species of this fam.
Planoides fusca, *Dalyell.*
Planaria hirudo, *Johnston.*

Astemma, *Oersted.*
rufifrons, *Johnston.*
filiformis, *Johnston.*
Cephalotrix, *Oersted.*
lineatus, *Dalyell.*
flustræ, *Dalyell.*
Tetrastemma, *Ehrenberg.*
varicolor, *Oersted.*
variegatum, *Dalyell.*
? algæ, *Dalyell.*
Borlasia, *Johnston.*
olivacea, *Johnston.*
octoculata, *Johnston.*
purpurea, *Johnston.*
Gesserensis, *Müller.*
striata, *Rathke.*
Ommatoplea, *Ehrenberg.*
gracilis, *Johnston.*
rosea, *Müller.*
alba, *Thompson.*
melanocephala, *Johnston.*
pulchra, *Johnston.*
Stylus, *Johnston.*
viridis, *Dalyell.*
purpureus, *Dalyell.*
fragilis, *Dalyell.*
fasciatus, *Dalyell.*
Lineus, *T. W. Simmons.*
longissimus, *Simmons.*
gracilis, *Goodsir.*
lineatus, *Johnston.*
murenoides, *D. Chiaje.*
fasciatus, *Johnston.*
viridis, *Dalyell.*
albus, *Dalyell.*
Meckelia, *Leuckart.*
annulata, *Montagu.*
tænia, *Dalyell.*
Serpentaria, *H. D. S. Goodsir.*
fragilis, *Goodsir.*
fusca, *Dalyell.*

Order II.
BDELLOMORPHA.

Fam. I.
Malacobdellidæ.

Malacobdella, *Blainville.*
grossa, *Müller.*
Valenciennæi, *Blanchard.*
anceps, *Dalyell.*

Order III. BDELLIDEA.

Fam. I. **Branchelliadæ.**

Branchellion, *Savigny.*
torpedinis, *Savigny.*

Fam. II. **Piscicolidæ.**

Pontobdella, *Leach.*
muricata, *Linn.*
verrucata, *Grube.*
areolata, *Leach.*
lævis, *Blainville.*
littoralis, *Johnston.*
campanulata, *Dalyell.*

Order IV. SCOLICES.

Fam. I. **Lumbricidæ.**

Sænuris, *Hoffmeister.*
lineata, *Müller.*
Clitellio, *Savigny.*
arenarius, *Müller.*
Valla, *Johnston.*
ciliata, *Müller.*

Order V. GYMNOCOPA.

Fam. I. **Tomopteridæ.**

Tomopteris, *Eschscholtz.*
onisciformis, *Grube.*

Order VI. CHÆTOPODA.

Fam. I. **Aphroditidæ.**

Aphrodita, *Leach.*
aculeata, *Linn.*
borealis, *Johnston.*
hystrix, *Savigny.*
Lepidonotus, *Leach.*
squamatus, *Linn.*
clava, *Montagu.*
impar, *Johnston.*
pharebratus, *Johnston.*
cirratus, *Fabr.*
semisculptus, *Leach.*
pellucidus, *Dyster.*
imbricatus, *Linn.*

Species not defined.
Aphrodita squamata, *Dalyell.*
lepidota, *Pallas.*
minuta, *Pennant.*
annulata, *Pennant.*
velox, *Dalyell.*
Lepidonotus floccosus ?, *Dalyell.*
Polynoë semisquamosa, *Williams.*

Polynoë, *Oersted.*
scolopendrina, *Savigny.*
Pholoë, *Johnston.*
inornata, *Johnston.*
eximia, *Dyster.*
Sigalion, *Aud. & M.-Edwards.*
boa, *Johnston.*

Fam. II.
Amphinomenidæ.

Euphrosyne, *Savigny.*
foliosa, *Aud. & M.-Edwards.*
borealis, *Oersted.*

Fam. III. **Euniceidæ.**

Eunice, *Aud. & M.-Edwards.*
Norvegica, *Linn.*
annulicornis, *Brit. Mus.*
antennata, *Savigny.*
Harassii, *Aud. & M.-Edw.*
sanguinea, *Montagu.*
margaritacea, *Williams.*
Northia, *Johnston.*
tubicola, *Müller.*
conchylega, *Sars.*
Lycidice, *Savigny.*
Ninetta, *Aud. & M.-Edw.*
rufa, *Gosse.*
Lumbrineris, *Blainville.*
tricolor, *Leach.*

Fam. IV. **Nereidæ.**

Nereis, *Cuvier.*
brevimana, *Johnston.*
pelagica, *Linn.*
diversicolor, *Müller.*
cærulea, *Linn.*
fimbriata, *Müller.*
imbecillis, *Grube.*
Dumerilii, *Aud. & M.-Edw.*
pulsatoria, *Montagu.*
Nereilepas, *Oersted.*
fucata, *Savigny.*
Heteronereis, *Oersted.*
lobulata, *Savigny.*
renalis, *Johnston.*
longissima, *Johnston.*
margaritacea, *Johnston.*

Fam. V. **Nephthyidæ.**

Nephthys, *Cuvier.*
cæca, *Fabr.*
longisetosa, *Oersted.*
Hombergii, *Cuv.* ? ?

Fam. VI. **Phyllodoceidæ.**

Phyllodoce, *Cuvier.*
lamelligera, *Turton.*
bilineata, *Johnston.*
maculata, *Linn.*
viridis, *Linn.*
ellipsis, *Dalyell.*
Griffithsii, *Johnston.*
cordifolia, *Dyster.*
Psamathe, *Johnston.*
punctata, *Müller.*

Fam. VII. **Glyceridæ.**

Glycera, *Savigny.*
mitis, *Johnston.*
dubia, *Blainville.*
capitata, *Oersted.*
nigripes, *Johnston.*
Goniada, *Aud. & M.-Edwards.*
maculata, *Oersted.*

Fam. VIII. **Syllidæ.**

Syllis, *Savigny.*
armillaris, *Müller.*
cornuta, *H. Rathke.*
prolifera, *Müller.*
? monoceros, *Dalyell.*
Gattiola, *Johnston.*
spectabilis, *Johnston.*
Myrianida, *M.-Edw.*
pinnigera, *Montagu.*
Ioida, *Johnston.*
macrophthalma, *Johnston.*

Fam. IX. **Amytideidæ.**

Amytidea, *Grube.*
maculosa (Nereis), *Montagu*

Fam. X. **Ariciadæ.**

Nerine, *Johnston.*
vulgaris, *Johnston.*
coniocephala, *Johnston.*

Doubtful species.
Nerine contorta (Nereis), *Dalyell.*

Spio, *Turton.*
filicornis, *Müller.*
seticornis, *Turton.*
crenaticornis, *Montagu.*
Leucodore, *Johnston.*
ciliatus, *Johnston.*
Ephesia, *Rathke.*
gracilis, *Rathke.*
Sphærodorum, *Oersted.*
peripatus, *Johnst.*
Cirratulus, *Lamarck.*
tentaculatus, *Mont.*
borealis, *Lamk.*
Dodecaceria, *Oersted.*
concharum, *Oersted.*

Fam. XI. **Opheliadæ.**

Ophelia, *Savigny.*
acuminata, *Oersted.*
Ammotrypane, *Rathke.*
limacina, *Rathke.*
Travisia, *Johnston.*
Forbesii, *Johnst.*
Eumenia, *Oersted.*
crassa, *Oersted.*

Fam. XII. **Siphonostomidæ.**

Siphonostoma, *Cuvier.*
uncinata, *Aud. & M.-Edw.*
Trophonia, *Cuvier.*
plumosa, *Müller.*

Fam. XIII. **Telethusidæ.**

Arenicola, *Savigny.*
piscatorum, *Lamk.*
branchialis, *Aud. & M.-Edw.*
ecaudata, *Johnst.*

Fam. XIV. **Maldaniadæ.**

Clymene, *Savigny.*
borealis, *Dalyell.*

Fam. XV. **Terebellidæ.**

Terebella, *Montagu.*
conchilega, *Pallas.*
littoralis. *Dalyell.*
cirrata, *Mont.*
nebulosa, *Mont.*
gigantea, *Mont.*
constrictor, *Mont.*
venustula, *Mont.*
tuberculata, *Dalyell.*
textrix, *Dalyell.*
maculata, *Dalyell.*
Venusia, *Johnston.*
punctata, *Johnst.*
Terebellides, *Sars.*
Strœmii, *Sars.*
Pectinaria, *Lamarck.*
Belgica, *Pallas.*
granulata, *Linn.*

Fam. XVI. **Sabellariadæ.**

Sabellaria, *Lamarck.*
Anglica, *Ellis.*
crassissima, *Lamk.*
lumbricalis, *Mont.*

Fam. XVII. **Serpulidæ.**

Arippasa, *Johnston.*
infundibulum, *Mont.*
Sabella, *Savigny.*
pavonina, *Savigny.*
penicillus, *Linn.*
vesiculosa, *Mont.*
bombyx, *Dalyell.*
Savignii, *Johnst.*
volutacornis, *Mont.*

Doubtful species.
Sabella unispira, *Sav.*
rosea (Amphitrite), *Sow.*
luna (Amphitrite), *Dal.*
curta (Amphitrite), *Mnt.*

Protula, *Risso.*
protensa, *Philippi.*
Dysteri, *Huxley.*
Serpula, *Linnæus.*
vermicularis, *Ellis.*
intricata, *Linn.*
reversa, *Mont.*
Berkeleyi, *Johnst.*
conica, *Flem.*
armata, *Flem.*
Dysteri, *Johnst.*
Ditrupa, *Berkeley.*
subulata, *Deshayes.*
Filograna, *Berkeley.*
implexa, *Berk.*
Othonia, *Johnston.*
Fabricii, *Johnst.*

Fam. XVIII. **Campontiadæ.**

Campontia, *Johnston.*
eruciformis, *Johnst.*

Fam. XIX. ? **Mæadæ.**

Mæa, *Johnston.*
mirabilis, *Johnst.*

Fam. XX. ? **Sipunculidæ.**

Syrinx, *Bohadsch.*
nudus, *Linn.*
papillosus, *Thomps.*
Harveii, *Forbes.*
Sipunculus, *Linnæus.*
Bernhardus, *Forbes.*
Macrorhynchopterus, *Rondel.*
Johnstoni, *Forbes.*
saccatus, *Flem.*
tenuicinctus, *M'Coy.*
Forbesii, *M'Coy.*
granulosus, *M'Coy.*
Pallasii, *Forbes.*

Fam. XXI. **Priapulidæ.**

Priapulus, *Lamarck.*
caudatus, *Flem.*

Fam. XXII. **Thalassemidæ.**

Thalassema, *Cuvier.*
Neptuni, *Gaërtner.*
Echiurus, *Cuvier.*
oxyurus, *Pall.*

Species inquirendæ.

Nereis, *Cuvier.*
iricolor, *Mont.*
margarita, *Mont.*
lineata, *Mont.*
maculosa, *Mont.*
rufa, *Penn.*
mollis, *Linn.*
octentaculata, *Mont.*
punctata, *Encycl. Méth.*
noctiluca, *Linn.*
pinnigera, *Mont.*
Aphrodita, *Leach.*
annulata, *Penn.*
minuta, *Penn.*
Spio, *Turton.*
seticornis, *Turt.*
crenaticornis, *Mont.*
calcarea, *Templeton.*
Branchiarius, *Mont.*
quadrangularis, *Mont.*
Diplotis, *Mont.*
hyalina, *Mont.*
Derris, *Adams.*
sanguinea, *Adams.*

ENTOZOA.

⁂ From Dr. Baird's British Museum Catalogue; and Dr. Bellingham's List of Irish Entozoa, in the 'Annals of Natural History,' 1844.

Species.	In what animals found.
Order NEMATOIDEA.	
Fam. **Filariadæ.**	
Filaria, *Müller.*	
? marina, *Linn.*	shad and cod.
inflexo-caudata, *Siebold*	porpoise.
sp.	red gurnard and mullet.
Trichosoma, *Rudolphi.*	
gracilis, *Bellingh.*	hake.
Spiroptera, *Rudolphi.*	
sp.	skate.
Fam. **Ascaridæ.**	
Ascaris, *Linnæus.*	
osculata, *Rud.*	seal.
aucta, *Rud.*	viviparous blenny.
rigida, *Rud.*	lophius.
capsularia, *Rud.*	cod, &c.
collaris, *Rud.*	flounder, &c.
clavata, *Rud.*	cod, &c.
constricta, *Rud.*	sea-scorpion, &c.
rotundata, *Rud.*	skate.
acus, *Bloch*	herring.
angulata, *Rud.*	lophius.
tenuissima, *Zeder*	whiting.
succisa, *Rud.*	lump-fish.
Fam. **Sclerostomidæ.**	
Cucullanus, *Müller.*	
minutus, *Rud.*	flounder.
heterochrous, *Rud.*	flounder.
foveolatus, *Lam.*	plaice and dab.
Stenurus, *Dujardin.*	
inflexus, *Rud.* (part.)	porpoise.
Prosthecosacter, *Diesing.*	
inflexus, *Rud.*	porpoise.
convolutus, *Kuhn*	porpoise.
Order TREMATODA.	
Fam. **Onchobothriadæ.**	
Octobothrium, *Leuckart.*	
lanceolatum, *Leuck.*	shad.
Fam. **Capsalidæ.**	
Capsala, *Bosc.*	
coccinea, *Cuv.*	sun-fish.
elongata, *Nitzsch*	sturgeon.
Fam. **Distomidæ.**	
Monostoma, *Zeder.*	
filicolle, *Rud.*	sea bream.
trigonocephalum, *Rud.*	turtle.
Distoma, *Retzius.*	
appendiculatum, *Rud.*	shad, &c.
hispidum, *Viborg*	sturgeon.
megastomum, *Rud.*	smooth shark.
microcephalum, *Baird*	spinous shark.
tumidulum, *Rud.*	pipe-fish.
fulvum, *Rud.*	skate.
varicum	salmon.
gibbosum ?, *Rud.*	haddock.
rufo-viride, *Rud.*	conger-eel.
reflexum ?	cyclopterus.
excisum, *Rud.*	mackerel.
scabrum, *Zeder*	whiting.
contortum, *Rud.*	sun-fish.
nigro-flavum, *Rud.*	sun-fish.
Hirudinella, *Garsin.*	
clavata, *Menzies*	Bonito.
Order ACANTHOCEPHALA.	
Fam. **Echinorhynchidæ.**	
Echinorhynchus, *Müller.*	
proteus, *Westrumb*	flounder.
acus, *Rud.*	cod, &c.
gibbosus, *Rud.*	herring.
strumosus, *Rud.*	seal.
Order CESTOIDEA.	
Fam. **Rhynchobothridæ.**	
Rhynchobothrium, *Blainville.*	
corollatum, *Abildg.*	smooth shark.
Tetrarhynchus, *Rudolphi.*	
megacephalus, *Rud.*	spotted dog-fish.
solidus, *Drum.*	salmon.
grossus, *Rud.*	salmon.
rugosus, *Baird*	salmon.
Tetrabothriorhynchus, *Dies.*	
barbatus, *Linn.*	lemon sole.
Fam. **Tæniadæ.**	
Bothriocephalus, *Rudolphi.*	
fragilis, *Rud.*	shad.
proboscideus, *Batsch.*	salmon, &c.
punctatus, *Rud.*	turbot, &c.
tumidulus, *Rud.*	ray.
microcephalus, *Rud.*	sun-fish.
coronatus, *Rud.*	skate.
corollatus, *Rud.*	dog-fish.
paleaceus, *Rud.*	dog-fish.
Fam. **Scolecidæ.**	
Scolex, *Müller.*	
polymorphus, *Rud.*	turbot, &c.
Order CYSTICA.	
Fam. **Cysticidæ.**	
Anthocephalus, *Rudolphi.*	
elongatus, *Rud.*	sun-fish.
granulosus ?, *Rud.*	whiting, &c.
paradoxus, *Drum.*	turbot.

Class ECHINODERMATA.

Order CRINOIDEA.

- Comatula, *Lamarck*.
  - rosacea, *Link*.
  - Celtica, *Barrett*.
  - Sarsii, *Düben & Koren*.

Order OPHIUROIDEA.

Fam. **Ophiuridæ.**

- Ophiura, *Lamarck*.
  - texturata, *Lamk*.
  - albida, *Forbes*.
- Ophiocoma, *Agassiz*.
  - neglecta, *Johnst*.
  - punctata, *Forbes*.
  - filiformis, *Müller*.
  - securigera, *D. & K.*
  - bellis, *Link*.
  - brachiata, *Mont*.
  - Ballii, *Thomps*.
  - Goodsiri, *Forbes*.
  - granulata, *Link*.
  - rosula, *Link*.
  - minuta, *Forbes*.

Subfam. **Euryalidæ.**

- Astrophyton, *Link*.
  - scutatum, *Link*.
- *Asteronyx, *Müll. & Troschel*.
  - Loveni, *M. & T.*

Order ASTEROIDEA.

Fam. **Asteriadæ.**

- Uraster, *Agassiz*.
  - glacialis, *Linn*.
  - rubens, *Linn*.
  - violacea, *Müller*.
  - hispida, *Penn*.
  - rosea, *Müller*.
- Echinaster, *Müller & Troschel*.
  - oculatus, *Penn*.
- Solaster, *Forbes*.
  - endeca, *Linn*.
  - papposa, *Linn*.
- Palmipes, *Link*.
  - membranaceus, *Retz*.
- Asterina, *Nardo*.
  - gibbosa, *Penn*.
- Goniaster, *Agassiz*.
  - Templetoni, *Thomps*.
  - equestris, *Gmelin*.
  - Abbensis, *Forbes*.
- Asterias, *Linnæus*.
  - aurantiaca, *Linn*.
- Luidia, *Forbes*.
  - fragilissima, *Forbes*.
  - Savignii, *Audouin*.

Order ECHINOIDEA.

Fam. **Cidaridæ.**

- Cidaris, *Leske*.
  - papillata, *Leske*.
- Echinus, *Linnæus*.
  - sphæra, *Müller*.
  - Flemingii, *Ball*.
  - miliaris, *Leske*.
  - lividus, *Lamk*.
  - melo, *Lamk*.
  - Norvegicus, *D. & K.*
  - neglectus, *Lamk*.

Fam. **Clypeasteridæ.**

- Echinocyamus, *Leske*.
  - pusillus, *Müller*.
- Echinarachnius, *Leske*.
  - placenta, *Gmelin*.

Fam. **Spatangidæ.**

- Spatangus, *Klein*.
  - purpureus, *Müller*.
- Brissus, *Klein*.
  - lyrifer, *Forbes*.
- Amphidotus, *Agassiz*.
  - cordatus, *Penn*.
  - roseus, *Forbes*.
  - gibbosus, *Barrett*.

Order HOLOTHUROIDEA.

Fam. **Pentactidæ.**

- Cucumaria, *Cuvier*.
  - frondosa, *Gunner*.
  - ? fucicola, *Forbes & Goodsir*.
  - pentactes, *Müller*.
  - ? Montagui, *Flem*.
  - ? Neillii, *Flem*.
  - ? dissimilis, *Flem*.
  - fusiformis, *Forbes & Goodsir*.
  - Hyndmanni, *Thomps*.
- Ocnus, *Forbes* (=Cucumaria?).
  - brunneus, *Forbes*.
  - lacteus, *Forbes & Goodsir*.
- Psolinus, *Forbes*.
  - brevis, *Forbes & Goodsir*.

Fam. **Thyonidæ.**

- Thyone, *Oken*.
  - fusus, *Müll*. (papillosa, *Abildg.*)
  - raphanus, *Düben & Koren*.
  - communis, *F. & G.* (Thyonidium, *D. & K.*)
  - Portlockii, *Forbes*.
  - Drummondii, *Thomps*.
  - pellucida, *Vahl* (Cucumaria hyalina, *F.*).
- Holothuria, *Linn*.
  - nigra, *Couch*.
  - intestinalis.
  - tubulosa, *Linn*.

Fam. **Psolidæ.**

- Psolus, *Oken*.
  - phantopus, *Linn*.
  - Forbesii.

Fam. **Synaptidæ.**

- Synapta, *Esch*.
  - inhærens, *Müll*.
  - digitata, *Mont*.

POLYZOA.

⁂ Classified as in the British Museum Catalogue by Mr. George Busk.

Order I. INFUNDIBULATA.

Suborder I. Cheilostomata.

Fam. II. **Salicornariadæ.**

- Salicornaria, *Cuvier*.
  - farciminoides, *Johnst*.
  - Johnstoni, *Busk*.
  - sinuosa, *Hassall*.
- Onchopora, *Busk*.
  - borealis, *Busk*.

Fam. III. **Cellulariadæ.**

- Cellularia, *Pallas*.
  - Peachii, *Busk*.
  - cuspidata, *Busk*.
- Menipea, *Lamouroux*.
  - ternata, *Ellis & Soland*.
- Scrupocellaria, *Van Beneden*.
  - scrupea, *Busk*.
  - scruposa, *Linn*.
- Canda, *Lamouroux*.
  - reptans, *Pall*.

Fam. IV. **Scrupariadæ.**

- Scruparia, *Oken*.
  - chelata, *Linn*.
  - clavata, *Hincks*.
- Salpingia, *Coppin*.
  - Hassallii, *Coppin*.
- Hippothoa, *Lamouroux*.
  - catenularia, *Jameson*.
  - divaricata, *Lamx*.
- Ætea, *Lamouroux*.
  - anguina, *Linn*.
  - truncata, *Landsb*.
  - recta, *Hincks*.
- Beania, *Johnston*.
  - mirabilis, *Johnst*.

Fam. VI. **Gemellariadæ.**

- Gemellaria, *Savigny*.
  - loricata, *Linn*.
- Notamia, *Fleming*.
  - bursaria, *Linn*.

Fam. VII. **Cabereadæ.**

- Caberea, *Lamouroux*.
  - Hookeri, *Flem.*
  - Boryi, *Aud.*

Fam. VIII. **Bicellariadæ.**

- Bicellaria, *De Blainville*.
  - ciliata, *Linn.*
  - Alderi, *Busk.*
- Bugula, *Oken.*
  - neritina, *Linn.*
  - flabellata, *J. V. Thomps.*
  - avicularia, *Pall.*
  - plumosa, *Pall.*
  - Murrayana, *Bean.*
  - turbinata, *Alder.*
  - fastigiata, *Fabr.*

Fam. IX. **Flustradæ.**

- Flustra, *Linn.*
  - foliacea, *Linn.*
  - papyracea, *Ellis.*
  - truncata, *Linn.*
  - Barleei, *Busk.*
- Carbasea, *Gray.*
  - papyrea, *Pall.*

Fam. X. **Membraniporidæ.**

- Membranipora, *De Blainville.*
  - membranacea, *Linn.*
  - pilosa, *Pall.*
  - coriacea, *Esper.*
  - lineata, *Linn.*
  - Flemingii, *Busk.*
  - Rosselii, *Audouin.*
  - Lacroixii, *Savigny.*
  - monostachys, *Busk.*
  - hexagona, *Busk.*
  - Pouilletii, *Audouin.*
  - spinifera, *Johnst.*
  - craticula, *Alder.*
  - unicornis, *Flem.*
  - imbellis, *Hincks.*
- Lepralia, *Johnston.*
  - Brongniartii, *Aud.*
  - Landsborovii, *Johnst.*
  - reticulata, *Macgillivray.*
  - auriculata, *Hassall.*
  - concinna, *Busk.*
  - verrucosa, *Esper.*
  - violacea, *Johnst.*
  - spinifera, *Johnst.*
  - trispinosa, *Johnst.*
  - coccinea, *Abildg.*
  - linearis, *Hassall.*
  - ciliata, *Pall.*
  - Gattyæ, *Landsb.*
  - Hyndmanni, *Johnst.*
  - variolosa, *Johnst.*
  - nitida, *Fabr.*
  - annulata, *Fabr.*
  - bispinosa, *Johnst.*
  - Peachii, *Johnst.*
  - ventricosa, *Hassall.*
  - melolontha, *Landsb.*
  - innominata, *Couch.*
  - punctata, *Hassall.*
  - figularis, *Johnst.*
  - pertusa, *Esper.*
  - Pallasiana.
  - labrosa, *Busk.*
  - simplex, *Johnst.*
  - Malusii, *Aud.*
  - granifera, *Johnst.*
  - hyalina, *Linn.*
  - ansata, *Johnst.*
  - unicornis, *Flem.*
  - ringens, *Busk.*
  - fissa, *Busk.*
  - Cecilii, *Audouin.*
  - Barleei, *Busk.*
  - canthariformis, *Busk.*
  - umbonata, *Busk.*
  - discoidea, *Busk.*
  - bella, *Busk.*
  - monodon, *Busk.*
  - alba, *Hincks.*
  - eximia, *Hincks.*
  - Woodiana, *Busk.*
- Alysidota, *Busk.*
  - Alderi, *Busk.*

Fam. XI. **Celleporidæ.**

- Cellepora, *Fabr.*
  - pumicosa, *Linn.*
  - Hassallii, *Johnst.*
  - vitrina, *Couch.*
  - ramulosa, *Linn.*
  - Skenei, *Ellis & Soland.*
  - tubigera, *Busk.*
  - armata, *Hincks.*
  - avicularis, *Hincks.*

Fam. XII. **Escharidæ.**

- Eschara, *Ray.*
  - foliacea, *Ellis & Soland.*
  - cervicornis, *Soland.*
  - cribraria, *Johnst.*
  - Retepora, *Lamarck.*
  - cellulosa, *Linn.*
  - Beaniana, *King.*

Suborder II. Cyclostomata.

Fam. I. **Tubuliporidæ.**

- Tubulipora, *Lamarck.*
  - patina, *Linn.*
  - hispida, *Flem.*
  - penicillata, *Johnst.*
  - truncata, *Jameson.*
  - lobulata, *Hassall.*
  - phalangea, *Couch.*
  - flabellaris, *Fabr.*
  - serpens, *Linn.*
  - hyalina, *Couch.*
- Diastopora, *Lamouroux.*
  - obelia, *Flem.*
- Idmonea, *Lamouroux.*
  - Atlantica, *Forbes.*
- Pustulipora, *De Blainville.*
  - proboscidea, *M.-Edw.*
  - deflexa, *Couch.*
  - Orcadensis, *Busk.*
- Alecto, *Lamouroux.*
  - granulata, *M.-Edw.*
  - major, *Johnst.*
  - dilatans, *Johnst.*
  - incurvata, *Hincks.*

Fam. II. **Crisiadæ.**

- Crisia, *Lamouroux.*
  - eburnea, *Linn.*
  - denticulata, *Lamk.*
  - aculeata, *Hassall.*
  - geniculata, *M.-Edw.*
- Crisidia, *M.-Edwards.*
  - cornuta, *Linn.*
  - setacea, *Couch.*

Suborder III. Ctenostomata.

Fam. I. **Alcyonidiadæ.**

- Alcyonidium, *Lamouroux.*
  - gelatinosum, *Pallas.*
  - hirsutum, *Flem.*
  - parasiticum, *Flem.*
  - mamillatum, *Alder.*
  - albidum, *Alder.*
  - hexagonum, *Hincks.*
- Cycloum, *Hass.*
  - papillosum, *Hass.*
- Sarcochitum, *Hass.*
  - polyoum, *Johnst.*

Fam. II. **Vesiculariadæ.**

- Amathia, *Lamouroux.*
  - lendigera, *Linn.*
- Vesicularia, *Thompson.*
  - spinosa, *Linn.*
- Valkeria, *Fleming.*
  - cuscuta, *Ellis.*
  - uva, *Linn.*
  - pustulosa, *Johnst.*
- Mimosella, *Hincks.*
  - gracilis, *Hincks.*
- Avenella, *Dalyell.*
  - fusca, *Dalyell.*
- Notella, *Gosse.*
  - stipata, *Gosse.*
- Bowerbankia, *Farre.*
  - imbricata, *Johnst.*
- Farrella, *Ehrenberg.*
  - repens, *Johnst.*
  - elongata.
  - gigantea.
  - pedicellata, *Alder.*
  - dilatata, *Hincks.*
- Anguinella, *Van Beneden.*
  - palmata, *V. Ben.*
- Buskia, *Alder.*
  - nitens, *Alder.*

Fam. III. **Pedicellinidæ.**

- Pedicellina, *Sars.*
  - echinata, *Sars.*
  - Belgica.
  - gracilis.

Subkingdom Cœlenterata.

Class HYDROZOA.

⁂ This list is compiled from Dr. Johnston's "British Zoophytes" (2nd edit.), Forbes's "British Naked-eyed Medusæ," and the works of Mr. Alder, Prof. Allman, Mr. Cobbold, Mr. Gosse, Professor Greene, Rev. Thomas Hincks, Professor Huxley, Dr. T. Strethill Wright, &c.

Order CORYNIDÆ.

Fam. I. **Coryniadæ.**

Clava, *Gmelin*.
multicornis, *Johnston* (repens, *T. S. Wright*; discreta, *Allman*).
cornea, *T. S. Wright*.
membranacea, *T. S. Wright*.
Vorticlava, *Alder*.
humilis, *Alder*.
Lar, *Gosse*.
Sabellarum, *Gosse*.
Hydractinia, *Van Beneden* (Podocoryna, *Sars*).
echinata, *Flem*.
carnea, *Sars*.
Myriothela, *Sars*.
arctica, *Sars*.
Clavatella, *Hincks*.
prolifera, *Hincks*.
Coryne, *Gaërtner*.
pusilla, *Ehr*.
Sarsii, *Lovén* (decipiens, *Dujardin*).
ramosa, *Ehr*. (Listerii, *Van Beneden*).
sessilis, *Gosse*.
gravata, *T. S. Wright*.
eximia, *Allman*.
implexa, *T. S. Wright* (Tubularia implexa, *Alder*; ? C. Briareus, *Allman*).
Cerberus, *Gosse*.
stauridia, *Dujardin*. [Should be referred to the next genus.]
Stauridia, *T. S. Wright*.
producta, *T. S. Wright*.
Trichydra, *T. S. Wright*.
pudica, *T. S. Wright*.

Fam. II. **Tubulariadæ.**

Eudendrium, *Ehrenberg*.
ramosum, *Linn*.
rameum, *Pall*.
capillare, *Alder*.
arbuscula, *T. S. Wright*.
Atractylis, *T. S. Wright*.
ramosa, *Van Beneden*.
repens, *T. S. Wright*.
sessilis, *T. S. Wright*.
Dicoryne, *Allman*.
conferta, *Alder* (Eudend. confertum, *Alder*).
Garveia, *T. S. Wright*.
nutans, *T. S. Wright*.
Bimeria, *T. S. Wright*.
vestita (Manicella fusca, *Allman*).
Tubularia, *Linnæus*.
indivisa, *Linn*.
Dumortierii, *Van Beneden*.
larynx, *Ellis*.
gracilis, *Harvey*.
Corymorpha, *Sars*.
nutans, *Sars*.
nana, *Alder*.

Order SERTULARIDÆ.

Fam. I. **Sertulariadæ.**

Halecium, *Oken*.
halecinum, *Ellis*.
Beanii, *Johnst*.
muricatum, *Ellis & Soland*.
labrosum, *Alder*.
tenellum, *Hincks*.
Sertularia, *Linnæus*.
polyzonias, *Linn*.
tricuspidata, *Alder*.
tenella, *Alder*.
Gayi, *Lamx*.
rugosa, *Ellis*.
rosacea, *Linn*.
pumila, *Linn*.
gracilis, *Hassall*.
Evansii, *Ellis & Soland*.
nigra, *Pallas*.
pinnata, *Pallas*.
alata, *Hincks*.
pinaster, *Ellis & Soland*.
Margareta, *Hassall*.
fallax, *Johnst*.
tamarisca, *Linn*.
abietina, *Linn*.
filicula, *Ellis & Soland*.
operculata, *Linn*.
argentea, *Ellis & Soland*.
cupressina, *Linn*.
fusca, *Johnst*.
Thuiaria, *Fleming*.
thuia, *Linn*.
articulata, *Pallas*.
Antennularia, *Lamarck*.
antennina, *Linn*.
ramosa, *Lamx*.
Plumularia, *Lamarck*.
falcata, *Linn*.
cristata, *Lamk*.
pennatula, *Ellis & Soland*.
myriophyllum, *Linn*.
tubulifera, *Hincks*.
pinnata, *Linn*.
setacea, *Ellis*.
Catherina, *Johnst*.
echinulata, *Lamk*.
similis, *Hincks*.
frutescens, *Ellis & Soland*.
halecioides, *Alder*.
obliqua, *Saunders* (Laomedea obliqua, *Johnst*.).

Fam. II. **Campanulariadæ.**

Laomedea, *Lamouroux*.
dichotoma, *Linn*.
longissima, *Pallas*.
geniculata, *Linn*.
flexuosa, *Hincks*.
Lovéni, *Allman*.
gelatinosa, *Pallas*.
angulata, *Hincks*.
neglecta, *Alder*.
pulchella, *Wyville Thomson*.
lacerata, *Johnst*.
tenuis, *Allman*.
acuminata, *Alder*.
Campanularia, *Lamarck*.
volubilis, *Linn*.
Johnstoni, *Alder*.
Hincksii, *Alder*.
raridentata, *Alder*.
integra, *Macgillivray*.
caliculata, *Hincks*.
verticillata, *Linn*.
[intertexta, *Couch*—a very doubtful species.]
Calicella, *Hincks*.
dumosa, *Flem*.
gracillima, *Alder*.
parvula, *Hincks*.
syringa, *Linn*.
fastigiata, *Alder*.
humilis, *Hincks*.
Reticularia, *Wyville Thomson*.
serpens, *Hassall*.
Grammaria, *Stimpson*.
ramosa, *Alder*.
Coppinia, *Hass*. [The position of this genus is doubtful.]
arcta, *Dalyell*.

Order CALYCOPHORIDÆ.

Fam. **Diphydæ.**

Diphyes, *Cuvier*.
appendiculata, *Eschscholtz*.

Order PHYSOPHORIDÆ.

Fam. I. **Stephanomiadæ.**

(?) Halistemma, *Huxley*.
rubrum, *Vogt*.

Fam. II. **Physaliadæ.**

- Physalia, *Lamarck.*
  - pelagica, *Eschscholtz.*
- Velella, *Lamarck.*
  - spirans, *Forsk.*

Order MEDUSIDÆ.

Fam. I. **Willsiadæ.**

- Willsia, *Forbes.*
  - stellata, *Forbes.*

Fam. II. **Oceanidæ.**

- Turris, *Lesson.*
  - digitalis, *O. F. Müller.*
  - neglecta, *Lesson.*
  - constricta, *Patterson.*
- Saphenia, *Eschscholtz.*
  - dinema, *Péron.*
  - Titania, *Gosse.*
- Oceania, *Péron.*
  - octona, *Flem.*
  - episcopalis, *Forbes.*
  - turrita, *Forbes.*
  - globulosa, *Forbes.*
  - ducalis, *Forbes & Goodsir.*
  - pusilla, *Gosse.*

Fam. III. **Æquoreadæ.**

- Stomobrachium, *Brandt.*
  - octocostatum, *Sars.*
- Polyxenia, *Eschscholtz.*
  - Alderi, *Forbes.*
- Æquorea, *Péron.*
  - Forskalii, *Forbes.*
  - Forbesiana, *Gosse.*
  - vitrina, *Gosse.*
  - formosa, *Greene.*
  - sp., *Greene.*

Fam. IV. **Circeadæ.**

- Circe, *Mertens.*
  - rosea, *Forbes.*

Fam. V. **Geryoniadæ.**

- Geryonia, *Péron.*
  - appendiculata, *Forbes.*
- Tima, *Eschscholtz.*
  - Bairdii, *Johnst.*
- Geryonopsis, *Forbes.*
  - delicatula, *Forbes.*
- Tiaropsis, *Agassiz.*
  - Pattersonii, *Greene.*
- Thaumantias, *Eschscholtz.*
  - pilosella, *Forbes.*
  - quadrata, *Forbes.*
  - aëronautica, *Forbes.*
  - octona, *Forbes.*
  - maculata, *Forbes.*
  - melanops, *Forbes.*
  - globosa, *Forbes.*
  - convexa, *Forbes.*
  - gibbosa, *Forbes.*
  - lineata, *Forbes.*
  - pileata, *Forbes.*
  - Sarnica, *Forbes.*
  - Thompsoni, *Forbes.*
  - hemisphærica, *O.F. Müller.*
  - inconspicua, *Forbes.*
  - punctata, *Forbes.*
  - lucifera, *Forbes.*
  - Buskiana, *Gosse.*
  - corynetes, *Gosse.*
  - undulata, *Forbes & Goodsir.*
  - confluens, *Forbes & Goodsir.*
  - achroa, *Cobbold.*
  - neglecta, *Greene.*
  - typica, *Greene.*
- Slabberia, *Forbes.*
  - halterata, *Forbes.*
  - catenata, *Forbes & Goodsir.*

Fam. VI. **Sarsiadæ.**

- Plancia, *Forbes & Goodsir.*
  - gracilis, *Forbes & Goodsir.*
- Goodsirea, *Strethill Wright.*
  - mirabilis, *S. Wright.*
- Sarsia, *Lesson.*
  - tubulosa, *Sars.*
  - pulchella, *Forbes.*
  - gemmifera, *Forbes.*
  - prolifera, *Forbes.*
- Hippocrene, *Mertens.*
  - Britannica, *Forbes.*
  - nigritella, *Forbes.*
  - pyramidata, *Forbes & Goodsir.*
  - crucifera, *Forbes & Goodsir.*
  - simplex, *Forbes & Goodsir.*
  - dinema, *Greene.*
- Lizzia, *Forbes.*
  - octopunctata, *Sars.*
  - blondina, *Forbes.*
  - sp., *Claparède.*
- Modeeria, *Forbes.*
  - formosa, *Forbes.*
- Diplonema, *Greene.*
  - Islandica, *Greene.*
- Euphysa, *Forbes.*
  - aurata, *Forbes.*
- Steenstrupia, *Forbes.*
  - rubra, *Forbes.*
  - flaveola, *Forbes.*
  - Owenii, *Greene.*

Order LUCERNARIDÆ.

Fam. I. **Lucernariadæ.**

- Lucernaria, *Müller.*
  - auricula, *Fabr.*
  - campanulata, *Lamx.*
  - fascicularis, *Flem.*
- Depastrum, *Gosse.*
  - stellifrons, *Gosse.*
- Carduella, *Allman.*
  - cyathiformis, *Sars.*

Fam. II. **Pelagidæ.**

- Aurelia, *Péron.*
  - aurita, *O. F. Müller.*
  - campanula, *O. Fabricius.*
- Cyanea, *Péron.*
  - capillata, *Linn.*
  - Lamarckii, *Péron.*
- Pelagia, *Péron et Lesueur.*
  - cyanella, *Péron et Lesueur.*
- Chrysaora, *Péron.*
  - hysoscella, *Linn.*

Fam. III. **Rhizostomidæ.**

- Cassiopeia, *Péron.*
  - lunulata, *Flem.*
- Rhizostoma, *Cuvier.*
  - pulmo, *Gmel.*

Class ACTINOZOA.

⁂ The list of Zoantharia is taken from Gosse's "Actinologia."

Order ZOANTHARIA.

Fam. I. **Actiniadæ.**

- Actinolobia, *Blainville.*
  - dianthus, *Blainv.*
- Sagartia, *Gosse.*
  - bellis, *Ellis.*
  - miniata, *Gosse.*
  - rosea, *Gosse.*
  - ornata, *Holdsworth.*
  - ichthystoma, *Gosse.*
  - nivea, *Gosse.*
  - sphyrodeta, *Gosse.*
  - pallida, *Holdsworth.*
  - pura, *Alder.*
  - coccinea, *Müll.*
  - troglodytes, *Johnst.*
  - viduata, *Müll.*
  - parasitica, *Johnst.*
  - chrysosplenium, *Cocks.*
- Adamsia, *Forbes.*
  - palliata, *Forbes.*
- Phellia, *Gosse.*
  - murocincta, *Gosse.*
  - gausapata, *Gosse.*
  - picta, *Gosse.*
  - Brodricii, *Gosse.*
- Gregoria, *Gosse.*
  - fenestrata, *Gosse.*
- Aiptasia, *Cocks.*
  - Couchii, *Cocks.*
- Anthea, *Gaërtner.*
  - cereus, *Ellis.*
- Actinia, *Linn.*
  - mesembryanthemum, *Ellis.*
- Bolocera, *Johnst.*
  - Tuediæ, *Johnst.*
  - eques, *Gosse.*
- Bunodes, *Gosse.*
  - gemmacea, *Ellis.*
  - thallia, *Gosse.*

  - Ballii, *Cocks.*
  - coronata, *Gosse.*
- Tealia, *Gosse.*
  - digitata, *Müll.*
  - tuberculata, *Cocks.*
  - crassicornis, *Müll.*
- Hormathia, *Gosse.*
  - margarita, *Gosse.*
- Stomphia, *Gosse.*
  - Churchiæ, *Gosse.*
- Ilyanthus, *Forbes.*
  - Scoticus, *Forbes.*
  - Mitchellii, *Gosse.*
- Peachia, *Gosse.*
  - hastata, *Gosse.*
  - undata, *Gosse.*
  - triphylla, *Gosse.*
  - cylindrica, *Reid.*
- Halcampa, *Gosse.*
  - chrysanthemum, *Peach.*
  - microps, *Gosse.*
- Edwardsia, *Quatrefages.*
  - callimorpha, *Gosse.*
  - carnea, *Gosse.*
  - Beautempsii, *Quatref.*
- Arachnactis, *Sars.*
  - albida, *Sars.*
- Cerianthus, *J. Haime.*
  - Lloydii, *Gosse.*
  - vermicularis, *Forbes.*
- Capnea, *Forbes.*
  - sanguinea, *Forbes.*
- Aureliania, *Gosse.*
  - angusta, *Gosse.*
  - heterocera, *Thomps.*
- Corynactis, *Allman.*
  - viridis, *Allman.*

Fam. II. **Zoanthidæ.**

- Zoanthus, *Cuvier.*
  - Couchii, *Johnst.*
  - sulcatus, *Gosse.*
  - Alderi, *Gosse.*

Fam. III. **Caryophylleadæ.**

- Cyathina, *Ehrenberg.*
  - Smithii, *Flem.*
- Paracyathus, *M.-Edwards*
  - Taxilianus, *Gosse.*
  - Thulensis, *Gosse.*
  - pteropus, *Gosse.*
- Desmophyllum, *Ehrenberg.*
  - Stokesii, *M.-Edwards.*
- Sphenotrochus, *M.-Edwards.*
  - Macandrewanus, *M.-Edw.*
  - Wrightii, *Gosse.*
- Ulocyathus, *Sars.*
  - arcticus, *Sars.*
- Oculina, *Lamarck.*
  - prolifera, *Linn.*
- Hoplangia, *Gosse.*
  - Durotrix, *Gosse.*
- Balanophyllia, *Wood.*
  - regia, *Gosse.*

Order ALCYONARIA.

Fam. I. **Pennatuladæ.**

- Pennatula, *Linnæus.*
  - phosphorea, *Linn.*
- Virgularia, *Lamarck.*
  - mirabilis, *Linn.*
- Pavonaria, *Cuvier.*
  - quadrangularis, *Pall.*

Fam. II. **Alcyonidæ.**

- Alcyonium, *Linnæus.*
  - digitatum, *Linn.*
  - glomeratum.
- Sarcodictyon, *Forbes.*
  - catenata, *Forbes.*
  - agglomerata.

Fam. III. **Gorgoniadæ.**

- Gorgonia, *Linnæus.*
  - verrucosa, *Linn.*
  - pinnata, *Linn.*
  - anceps, *Ellis.*
- Primnoa, *Lamarck.*
  - lepadifera, *Linn.*

Order CTENOPHORA.

Fam. I. **Cydippidæ.**

- Cydippe, *Esch.*
  - pileus, *Müll.*
  - Flemingii, *Forbes.*
  - infundibulum, *Müll.*
  - lagena, *Forbes.*
  - pomiformis, *Paterson.*

Fam. II. **Calymnidæ.**

- Bolina, *Paterson.*
  - Hibernica, *Paterson,*

Fam. III. **Beroidæ.**

- Beroë, *Müller.*
  - cucumis, *Fabr.*
  - fulgens, *Flem.*
  - borealis, *Less.*
- Alcinoë, *Cuv.*
  - rotunda.
  - Smithii.

Subkingdom Protozoa.

FORAMINIFERA.

⁂ This list of British Foraminifera is taken from Prof. Williamson's "Recent Foraminifera of Great Britain," published by the Ray Society.

- Proteonina, *Williamson.*
  - fusifornis, *Williamson.*
  - pseudospiralis, *Williamson.*
- Orbulina, *D'Orbigny.*
  - universa, *D'Orb.*
- Lagena, *Walker.*
  - vulgaris, *Williamson.*
    - var. clavata.
    - var. perlucida.
    - var. semistriata.
    - var. striata.
    - var. interrupta.
    - var. gracilis.
    - var. substriata.
- Entosolenia, *Ehrenberg.*
  - globosa, *Walker.*
    - var. lineata.
  - costata, *Williamson.*
  - marginata, *Walker.*
    - var. lucida.
    - var. ornata.
    - var. lagenoides.
    - var. quadrata.
  - squamosa, *Mont.*
    - var. scalariformis.
    - var. catenulata.
    - var. hexagona.
- Lingulina, *D'Orbigny.*
  - carinata, *D'Orb.*
- Nodosaria, *Lamarck.*
  - radicula, *Linn.*
  - pyrula, *D'Orb.*
- Dentalina, *D'Orbigny.*
  - subarcuata, *Mont.*
    - var. jugosa.
  - legumen, *Linn.*
    - var. linearis.
- Frondicularia, *Defrance.*
  - spathulata, *Williamson.*
  - Archiaciana, *D'Orb.*
- Cristellaria, *Lamarck.*
  - calcar, *Linn.*
    - var. rotifera.
    - var. oblonga.
  - subarcuatula, *Walker.*
    - var. costata.
- Nonionina, *D'Orbigny.*
  - Barleeana, *Williamson.*
  - crassula, *Walker.*
  - Jeffreysii, *Williamson.*
  - elegans, *Williamson.*
- Nummulina, *D'Orbigny.*
  - planulata, *Lam.*
- Polystomella, *Lamarck.*
  - crispa, *Linn.*
  - umbilicatula, *Walker.*
    - var. incerta.
- Peneroplis, *Montfort.*
  - planatus, *Ficht. & Moll.*
- Patellina, *Williamson.*

- corrugata, *Williamson.*
- Rotalina, *D'Orbigny.*
  - Beccarii, *Linn.*
  - inflata, *Mont.*
  - turgida, *Williamson.*
  - oblonga, *Williamson.*
  - concamerata, *Mont.*
  - nitida, *Williamson.*
  - mamilla, *Williamson.*
  - ochracea, *Williamson.*
  - fusca, *Williamson.*
- Globigerina, *D'Orbigny.*
  - bulloides, *D'Orb.*
- Planorbulina, *D'Orbigny.*
  - vulgaris, *D'Orb.*
- Truncatulina, *D'Orbigny.*
  - lobatula, *Walker.*
- Bulimina, *D'Orbigny.*
  - pupoides, *D'Orb.*
    - var. marginata.
    - var. spinulosa.
    - var. fusiformis.
    - var. compressa.
    - var. convoluta.
  - elegantissima, *D'Orb.*
  - scabra ?, *Williamson.*
- Uvigerina, *D'Orbigny.*
  - pygmæa, *D'Orb.*
  - angulosa, *Williamson.*
- Cassidulina, *D'Orbigny.*
  - lævigata, *D'Orb.*
  - obtusa, *Williamson.*
- Polymorphina, *D'Orbigny.*
  - lactea, *Walker.*
    - var. acuminata.
    - var. oblonga.
    - var. fistulosa.
    - var. concava.
    - var. communis.
  - myristiformis, *Williamson.*
- Textularia, *Defrance.*
  - cuneiformis, *D'Orb.*
    - var. conica.
  - variabilis, *Williamson.*
    - var. spathulata.
    - var. difformis.
    - var. lævigata.
- Biloculina, *D'Orbigny.*
  - ringens, *D'Orb.*
    - var. carinata.
- Spiroloculina, *D'Orbigny.*
  - depressa, *D'Orb.*
    - var. rotundata.
    - var. cymbium.
- Miliolina, *Williamson.*
  - trigonula, *Lamk.*
  - seminulum, *Linn.*
    - var. oblonga.
    - var. disciformis.
  - bicornis, *Walker.*
    - var. elegans.
    - var. angulata.
- Vertebralina, *D'Orbigny.*
  - striata, *D'Orb.*
- Spirillina, *Ehrenberg.*
  - foliacea, *Philippi.*
  - perforata, *Schultze.*
  - arenacea, *Williamson.*
  - margaritifera, *Williamson.*

LIST OF BRITISH SPONGES.

- Tethya, *Lamarck.*
  - cranium, *Johnst.* (not *Müll.*)
  - lyncurium, *Johnst.*
- Geodia, *Lamarck.*
  - Zetlandica, *Johnst.*
- Pachymatisma, *Bowerbank.*
  - Johnstonia, *Bowb.* (Halichondria, *Johnst.*)
- Halichondria, *Fleming.*
  - panicea, *Johnst.*
  - coalita, *Johnst.*
  - coccinea, *Bowb. MS.*
  - glabra, *Bowb. MS.*
  - inconspicua, *Bowb. MS.*
  - caduca, *Bowb. MS.*
  - distorta, *Bowb. MS.*
  - Dickiei, *Bowb. MS.*
  - Batei, *Bowb. MS.*
  - lingua, *Bowb. MS.*
  - corrugata, *Bowb. MS.*
  - granulata, *Bowb. MS.*
  - Thompsoni, *Bowb. MS.*
  - plumosa, *Johnst.*
  - incrustans, *Johnst.*
  - fallax, *Bowb. MS.*
  - paupera, *Bowb. MS.*
  - Clarkei, *Bowb. MS.*
  - variantia, *Bowb. MS.*
  - Hyndmanni, *Bowb. MS.*
  - nigricans, *Bowb. MS.*
  - Ingalli, *Bowb. MS.*
  - fimbriata, *Bowb. MS.*
  - albula, *Bowb. MS.*
  - farinaria, *Bowb. MS.*
- Hymeniacidon, *Bowerbank* (Halichondria, *Johnst.*).
  - Thomasii, *Bowb. MS.*
  - fragilis, *Bowb. MS.*
  - Brettii, *Bowb. MS.*
  - albescens, *Johnst.*
  - caruncula, *Bowb. MS.*
  - Alderi, *Bowb. MS.*
  - perlævis, *Johnst.*
  - aurea, *Johnst.*
  - pachyderma, *Bowb. MS.*
  - crustula, *Bowb. MS.*
  - sanguinea, *Johnst.*
  - armatura, *Bowb. MS.*
  - floreum, *Bowb. MS.*
  - carnosa, *Bowb. MS.*
  - viridans, *Bowb. MS.*
  - sulphurea, *Bowb. MS.*
  - clavigera, *Bowb. MS.*
  - subclavata, *Bowb. MS.*
  - lactea, *Bowb. MS.*
  - Dujardinii (Halisarca), *Johnst.*
  - celata, *Johnst.*
- Halina, *Bowerbank* (Halichondria, *Johnst.*).
  - suberea (Halichondria), *Johnst.*
  - ficus, *Johnst.*
  - carnosa, *Johnst.*
  - Bucklandi, *Bowb. MS.*
- Isodictya, *Bowerbank* (Halichondria, *Johnst.*).
  - Peachii, *Bowb. MS.*
  - rosea, *Bowb. MS.*
  - permollis, *Bowb. MS.*
  - indistincta, *Bowb. MS.*
  - indefinita, *Bowb. MS.*
  - Macandrewii, *Bowb. MS.*
  - dichotoma, *Bowb. MS.*
  - cinerea, *Johnst.*
  - ramusculus, *Bowb. MS.*
  - simulo, *Bowb. MS.*
  - mammeata, *Bowb. MS.*
  - fucorum, *Johnst.*
  - Alderi, *Bowb. MS.*
  - Normani, *Bowb. MS.*
  - lobata, *Johnst.*
  - Barleei, *Bowb. MS.*
  - gracilis, *Bowb. MS.*
  - Gregorii, *Bowb. MS.*
  - Beanii, *Bowb. MS.*
  - clava, *Bowb. MS.*
  - infundibuliformis, *Johnst.*
- Desmacidon, *Bowerbank* (Halichondria, *Johnst.*).
  - ægagropila, *Johnst.*
  - fruticosa, *Johnst.*
- Raphyrus, *Bowerbank.*
  - Griffithsii, *Bowb. MS.*
- Dictyocylindrus, *Bowerbank* (Halichondria, *Johnst.*).
  - stuposus, *Johnst.*
  - Howsei, *Bowb. MS.*
  - ramosus, *Johnst.*
  - aculeatus, *Bowb. MS.*
  - ventilabrum, *Bowb. MS.*
  - fascicularia, *Bowb. MS.*
  - rugosus, *Bowb. MS.*
- Haliclona, *Bowerbank* (Halichondria, *Johnst.*).
  - palmata, *Johnst.*
  - Montagui, *Johnst.*
  - pygmæa, *Bowb.*
  - seriata, *Johnst.*
  - simulans, *Johnst.*
  - columbæ, *Johnst.*
  - gracilenta, *Bowb. MS.*
- Microciona, *Bowerbank, MS.*
  - atro-sanguinea, *Bowb. MS.*
  - armata, *Bowb. MS.*
  - carnosa, *Bowb. MS.*
  - ambigua, *Bowb. MS.*

- lævis, *Bowb. MS.*
- spinulenta, *Bowb. MS.*

Hymeraphia, *Bowerbank, MS.*

- vermiculata, *Bowb. MS.*
- stellifera, *Bowb. MS.*
- clavata, *Bowb. MS.*

Hymedesmia, *Bowerbank, MS.*

- Zetlandica, *Bowb. MS.*

Halyphysema, *Bowerbank, MS.*

- Tumanowiczii, *Bowb. MS.*

Euplectella, *Owen.*

- mammillaris (Halichondria), *Johnst.*
- brevis, *Bowb. MS.*
- robusta, *Bowb. MS.*

Halicnemia, *Bowerbank, MS.*

- patera, *Bowb. MS.*

Phakellia, *Bowb. MS.* (Halichondria, *Johnst.*).

- ventilabrum, *Johnst.*

Dysidea, *Johnston.*

- fragilis, *Johnst.*

Spongia, *Linnæus.*

- pulchella, *Johnst.*
- limbata, *Johnst.*

Grantia, *Fleming.*

- compressa, *Johnst.*
- ciliata, *Johnst.*
- ensata, *Bowb. MS.*
- tessellata, *Bowb. MS.*

Leuconia, *Bowerbank* (Grantia, *Johnst.*).

- nivea, *Johnst.*
- fistulosa, *Johnst.*

Leucosolenia, *Bowerbank, MS.* (Grantia, *Johnst.*).

- botryoides, *Johnst.*
- coriacea, *Johnst.*
- lacunosa, *Johnst.*
- contorta, *Bowb. MS.*

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

MATHEMATICS.

Address by the Rev. Prof. PRICE, *M.A., F.R.S., President of the Section.*

GENTLEMEN,—A custom has prevailed at our Meetings for some years for the President of each Section to make a short address at the opening. The object of it I take to be twofold; first, to explain to new members the nature of the business which we have to transact; and, secondly, to suggest to all the course of procedure, and the distribution of subject most convenient for the conduct of our business. The area of scientific research which this Section covers is very large, larger perhaps than that of any other; and its subjects vary so much, that while to some of those who frequent this room certain papers may appear dull, yet to others they will be full of interest. There are many and very good reasons why these subjects should be grouped. Some of them possess, probably in the highest degree attainable by the human intellect, the characteristics of perfect and necessary science; while others are at present little more than a conglomeration of observations, made indeed with infinite skill and perseverance, and of the greatest value; capable probably in time of greater perfection, nay, perhaps, of most perfect forms, but as yet in their infancy, scarcely indicating the process by which that maturity will be arrived at, and containing hardly the barest outline of their ultimate laws. We have indeed sciences intermediate to these two extremes, in which some of the laws are already capable of mathematical expression, and from which results have been derived, and still many phenomena are as yet not brought within their comprehension. But as all subjects which we regard in this Section are of one type, so are they rightly combined; and it will be, I venture to think, an evil day for natural knowledge, when we cease to regard the forms of the sciences of space, number, and motion, as those to which all others ought to assimilate themselves.

Now first of all in our Section stand Mathematics, both pure and applied. These, indeed, require very heavy and arduous study, inasmuch as they have peculiar nomenclature, language, and processes, and thus it is only to the few generally who have made them their particular study that they offer great interest. Mathematics have also now become so large in their grasp and so curious in their details, that I am, I am sure, only expressing the opinions of most analysts when I say that the whole of a man's life is not sufficient for more than one branch of it. Indeed, and we are proud to say so, some members of this Association are devoting whole lives, and intellects too of the highest order, to the advancement of our knowledge in a particular direction. Take, for instance, the theory of homogeneous forms: in the history of science the names of Boole, Cayley, Sylvester will always be recorded, and in scientific treatises their labours will find a place. Or take again the theory of elliptic functions, or the calculus of probabilities; the difficulties of these subjects require the utmost tension of the human mind, and even then they transcend its limits. To many of the usual attendants on this Section, these and kindred subjects may be dry and uninteresting. Well, if they are so to any of you, I must beg you to bear with us for a short time; these things have a deep and significant meaning; and be assured too that they are not uninteresting to all; to many they give the purest pleasure; and I must ask you not to grudge them *that* during the few papers on the higher mathematics which we shall probably have. In passing, too, I would remind you that very frequently our knowledge of natural phenomena depends on certain integrals, the properties of which can only be studied with a profound knowledge of the higher mathematics; and thus the progress of one branch of knowledge depends on another, and is frequently stopped by our ignorance of that.

To most of us, probably, the questions of applied mathematics will have greater interest; we are more familiar with the laws of nature, the mathematical interpretation of which, mixed mathematics, as they are called, take cognizance of; we most eagerly catch at the results of those laws. Consider the Newtonian law of gravitation in its most general form; in its highest development in the lunar and planetary theories, a dry mathematical paper will thin our room; an astronomical paper will often fill it; and now too, perhaps, more than heretofore; for our interest in the subject has been keenly aroused of late. The lunar disturbances have been, as you know, calculated with greater precision, and new results have been arrived at, which exhibit certain discrepancies relatively to the old. I need do no more than allude to what has lately taken place at our own Royal Astronomical Society and at the French Academy; and express a hope that we shall have some communication on this subject from those who are here present, and are so well qualified to give it. Mathematicians, however, have been startled by an announcement that "what is commonly called mathematical evidence is not so certain as many persons imagine; and that it ultimately depends on moral evidence;" and moreover we are told that the "results of long and complicated mathematical calculations are not more than probably true." This we can hardly believe; it takes us quite by surprise, and we hope for further light; if, however, we must wait for light, we must wait patiently; let us not forestal a conclusion which many of us venture to think is as yet, not to say more, unproved; let us wait for the new lunar theories, which are as yet unpublished, and for the new lunar tables, which are the results of these theories. I am told, however, already that Baron Plana has corrected his calculations, and that he finds the results arrived at by Delaunay and Adams to be in accordance with his amended formulæ. These new lunar calculations have taken us by surprise; but again I would say let us wait, "magna est veritas et prævalebit."

We are desirous, so far as is possible consistently with the convenience of contributors, to take the papers on mathematical subjects on the early days of our meeting; and we shall be glad therefore if members who have papers on these subjects will announce them to the Secretaries without delay. And before I proceed further, we have a debt to pay, due by the cultivators of these branches of science, to those who have lately contributed reports on particular parts of our science to the British Association;—to Mr. Cayley for his report on the present state of Theoretical Dynamics, and to Mr. Smith for the first part of his report on the Theory of Numbers. It is only they who have had to go through the existing literature in any one problem, say the Lagrangian equations, or the theory of the motion of a material system, that can form an adequate value of such papers as those I refer to: the literature is catalogued, indexed, and analysed; we know thereby all that has been done up to a certain point, and in our subsequent investigations our commencement starts from the close of other men's labours. We are hereby prevented from travelling over other men's ground; and we avoid that most unsatisfactory plagiarism of them, "qui nostra ante nos dixerunt." Vast and various are the benefits of our Association; but I am inclined to consider as one of the greatest, the series of valuable reports which our published volumes contain; and those last reports to which I have referred, for their learning, their deep research, their comprehensive views of the theories explained in them, will maintain the character shared by their predecessors. While we lament the loss of Dr. Peacock and others, to whom we owe the very able reports contained in the early volumes of our proceedings, we are proud to have worthy successors in our present talented contributors.

We propose, next in order, to take those papers which treat of subjects within the grasp of mathematical symbols, at least partially, if not wholly; those whose laws are sufficiently general for functional symbols, and from particular forms of which by mathematical processes other truths may be derived. Such are the subjects of Light, Heat, Sound, Electricity, Magnetism; we propose to take these subjects in the latter days of this week, and the first day of next. We shall, of course, consult the convenience of contributors; but it will tend, we think, to the orderly arrangement of our business if this order can be adopted. Vast indeed in their subjects are these sciences; and as discoveries are being daily made in them, we have a right to expect some interesting communications, either in the way of mathematical deduction from received laws, or as mathematical explanations of observed phenomena, or as simple experiments. I cannot help observing here the advantage of combining these sciences in the same Section with pure mathematics; it seems to indicate that the laws of all are to be brought to the same test,—to the never-failing, to the unerring accuracy of measurement and number; we show hereby the character of the knowledge we are in search of; not fortuitous observation, but precise laws. The mind will wander in its imagination; there is, indeed, no boundary to it; once, however, bring it back to the severe test of number and weight and measurement, and the discovery or the observation becomes valuable for its precision; it thus leads to general laws, and sound mathematical reasoning derives from them the results they are pregnant with.

And, finally, we come to the facts of meteorology and its kindred subjects, many of which are scarcely yet brought within any law at all; analogies have been traced, and concurrent events have been indicated in many cases; little, however, has been done towards a satisfactory proof of a connexion between cause and effect. It is true that curves are traced, which purport to exhibit these effects; and they do so most graphically; but, as mathematicians say, these curves are traced only by *points*, and the law is not known, or, in other words, we do not know the equation of the curve; so long as this is the case, our knowledge lacks precision. These papers, however, are frequently valuable, because they supply us with accurately observed facts, which will doubtless hereafter be brought within a law. This, however, I suppose at present to be the state of the case; but we must not despise the lesser light because we have not the greater. I cannot pass over this class of papers (papers of observed facts) without alluding to the loss which we all feel in the death of the late able Professor of Geometry, Professor Baden Powell. For some years past has he continued his reports on the meteors or falling stars, or whatever you call them; this year we have his last report, which, indeed, he has not lived to finish, but has been placed in the hands of Mr. Glaisher, and completed by him. In some of these subjects we shall, I hope, obtain large accessions to our knowledge.

Some few years ago I remember reading a complaint made by an eminent philosopher on the decay of mathematical knowledge in Great Britain, and especially in that of physico-mathematical knowledge. It is not my duty to make invidious distinctions; but I am sure I am repeating the now common opinion of foreigners when I tell you that that complaint was made in quite the infancy of some of our older philosophers, and before the days of Cayley, Sylvester, Boole, Maccullagh, Stokes, W. Thomson, and Adams. To this revival of science amongst us, doubtless, many causes have contributed; and I believe that the periodical meetings of this Association have done good service towards that revival; we have hereby become acquainted with others who are engaged in the same pursuits as ourselves, and stores of knowledge are communicated. Let us, however, bear in mind that our Association is formed for the advancement of science, and that we do not meet to hear of old things again in the old form; our motto is "progress." Old things we do not discard, for they may be put before us in new forms: but we meet especially to promote the advance of the boundaries of natural knowledge, and we ask our members and others to lay before us the results of their investigations. And not only in the papers which shall be read, but also in the elucidation of any difficulties which authors may favour us with, and in the discussions which it is my duty to invite you to take upon these papers, will additions to our knowledge be made; and many remarks will, I venture to think, be made pregnant with matter for thoughtful meditation hereafter. In all these discussions difference of opinion will doubtless arise; but I am sure that a spirit of friendly and mutual concession will prevail; and that in our search after truth we shall gladly and readily attribute to those who differ from us the same pure motives which we claim to ourselves.

On some Solutions of the Problem of Tactions of Apollonius of Perga by means of Modern Geometry. By Dr. BRENNECKE, *of Posen.*

The author suggested a new solution, depending on a remarkable property of the centres of similitude of three given circles; *e. g.* a circle described around an external centre of similitude, with a radius equal to the geometrical proportional of its potential distances from the two circles, intersects all homogeneously touching circles orthogonally (around an internal centre all heterogeneously touching circles). Such a circle is called a potential circle. To get the two circles which touch the three given circles simultaneously internally or externally, take two external centres of similitude, draw the two potential circles, find their radical axis, which will contain the centre of similitude of the two circles which cut the three given circles in the same time externally or internally. By combining the three external centres of similitude, you find three potential circles and three radical axes, which all three coincide. Having found this straight line, which contains the centres, it is easy to find the centres themselves by introducing a fourth circle, the reflected mirror-image as it were of any of the three given circles, by means of the found radical axis, and finding out the two circles which touch the two symmetrical circles and any one of the three given circles. Dr. Brennecke has treated the subject at large in a book which has just now been published at Berlin, 'Die Berührungsaufgabe für Kreis und Kugel,' Th. Chr. Fr. Enslin, 1860, 8vo, illustrated by eighty-four diagrams, in which all information will be found concerning the most renowned problem of geometry, concerning the problem of tactions of three given circles or four given spheres.

On a New General Method for establishing the Theory of Conic Sections.
By the Rev. JAMES BOOTH, *LL.D., F.R.S.*

On the Relations between Hyperconic Sections and Elliptic Integrals.
By the Rev. JAMES BOOTH, *LL.D., F.R.S.*

In this communication the author extended the analogies that the Continental and English geometers had established between elliptic integrals of the third order under the circular form, and the arcs of spherical conic sections, to the corresponding relations between elliptic integrals of the third order and logarithmic form to the arcs of curves described in the surface of a paraboloid.

On Curves of the Fourth Order having Three Double Points.
By A. CAYLEY, *F.R.S.*

The paper is a short notice only of researches which the author is engaged in with reference to curves of the fourth order having three double points. A curve of the kind in question is derived from a conic by the well-known transformation of substituting for the original trilinear coordinates their reciprocals; and the species of the curve of the fourth order depends on the position of the conic with respect to the fundamental triangle.

On the Trisection of an Angle. By PATRICK CODY.

On the Roots of Substitutions. By the Rev. T. P. KIRKMAN, *A.M., F.R.S.*

To determine the number of roots of a given degree, of a substitution θ made with n letters, and of the rth order. A substitution θ which has not two circular factors of the same order, has no roots which are not found among the series

$$1+\theta+\theta^2+..+\theta^{r-1}$$

of its powers.

A substitution which has two or more circular factors of the same order, will have roots of an order superior to its own, and therefore not among its power.

Thus the substitution of the 3rd order made with 9 elements,

$$\theta=\frac{231564897}{123456789},$$

has 1 square root of the 3rd order, 9 square roots of the 6th order, 9 fourth roots of the 6th order, 18 cubic roots of the 9th order, and 18 sixth roots of the 9th order. These roots can be enumerated by a simple general method for θ of any order, made with n letters.

The fundamental theorem is the following:—

If $n = Aa + Bb + Cc + \ldots\ldots$, the number of different groups of the order K, which is the least common multiple of ABC . . . ., of the form

$$1, \theta, \theta^2, \ldots \theta^{K-1},$$

where θ has a circular factors of the order A, b of the order B, &c., is ($\pi n = 1 \,.\, 2 \,.\, 3 \ldots n$),

$$\frac{\pi n}{R_K \, A^a \, B^b \, C^c \ldots \pi a \, \pi b \, \pi c \ldots},$$

R_K being the number of integers, unity included, which are less than K and prime to it.

The partition $$n = 9 = 3 \,.\, 3 = Aa$$

gives $$\frac{\pi 9}{R_3 \, 3^3 \,.\, \pi 3} = 8 \,.\, 7 \,.\, 5 \,.\, 4$$

groups, $$1 \theta \theta^2, \qquad \ldots\ldots\ldots\ldots \qquad (G)$$

of the third order, which is that of θ and of θ^2.

The partition

$$n = 9 = 6 \,.\, 1 + 3 \,.\, 1 = Aa + Bb$$

gives $$\frac{\pi 9}{R_6 \,.\, 6 \,.\, 3} = 8 \,.\, 7 \,.\, 6 \,.\, 5 \,.\, 3 \,.\, 2$$

groups, $$1 \phi \phi^2 \ldots \phi^5, \qquad \ldots\ldots\ldots\ldots \qquad (H)$$

of the 6th order. Every group (H) contains a group (G), namely,

$$1 \phi^2 \phi^4,$$

and ϕ of the 6th order is the square root of ϕ^2 of the 3rd order, and the fourth root of ϕ^4 of the 3rd order. Also ϕ^5 of the 6th order is the square root of ϕ^4, and the fourth root of ϕ^2.

The number of groups (H) being nine times that of the group (G), the group $1\theta\theta^2$ will be comprised in nine different groups (H); that is, θ has nine square roots of the 6th order, and nine fourth roots of the same order.

The partition

$$n = 9 = 9 \,.\, 1 = Aa$$

gives $$\frac{\pi 9}{R_9 \; 9} = 8 \,.\, 7 \,.\, 5 \,.\, 4 \,.\, 3 \,.\, 2$$

groups, $$1 \psi \psi^2 \ldots \psi^8, \qquad \ldots\ldots\ldots\ldots \qquad (J)$$

of the 9th order. This comprises the group (G),

$$1 \psi^3 \psi^6,$$

where ψ^3 has the cube roots $\psi \; \psi^4 \; \psi^7$ of the 9th order, and the sixth roots $\psi^2 \; \psi^5 \; \psi^8$ of the same order. There are six times as many groups (J) as groups (G). Therefore

$$1 \theta \theta^2$$

will be found in six groups (J), and either θ or θ^2 has 18 cube roots, and 18 sixth roots all of the 9th order.

In the same manner it is easily proved that the substitution of the 2nd order ($n = 8$),

$$\theta' = \frac{34127856}{12345678},$$

which has four circular factors of the 2nd order, has twelve square roots all of the 4th order. These form with unity and θ' the two groups following,

12345678	12345678
34127856	34127856
58763214	23418567
76581432	41236785
23416785	78561234
41238567	56783412
87652143	85674123
65874321	67852341

which are of the form (IV.) discovered by Mr. Cayley (Phil. Mag. vol. viii. 1859, p. 34), who there first enumerated the forms of groups of eight.

Two such groups can be completed with unity, and any one of the

$$\frac{\pi 8}{R_2 . 4^2 . \pi 2} = 7 . 6 . 5 . 3 . 2$$

substitutions of the form θ'.

It is easy to form groups of Mr. Cayley's form (II.) ; *e. g.*,

12345678
34127856
23416785
41238567
56781234
78563412
67852341
85674123

which is one of the ***grouped groups*** whose general theory I have handled in a memoir which will shortly see the light.

On a new Proof of Pascal's *Theorem. By the* Rev. T. Rennison, *M.A.*

On Systems of Indeterminate Linear Equations.

By H. J. Stephen Smith, *M.A., Fellow of Balliol College, Oxford.*

The object of this communication was to point out the connexion which exists between particular solutions of indeterminate linear equations, and their most general solution. The principle upon which this connexion depends may be explained in a very particular case. Let the sytem of indeterminate equations reduce itself to the single equation

$$Ax+By+Cz=0, \quad \ldots\ldots\ldots\ldots \quad (1)$$

in which we may suppose A, B, C to have no common divisor; let also a, b, c and a', b', c' be two different solutions of that equation in integral numbers; then, ***if the three numbers***

$$bc'-b'c, \quad ca'-ac', \quad ab'-a'b \quad \ldots\ldots\ldots\ldots \quad (2)$$

admit of no common divisor, the complete solution of the indeterminate equation is contained in the formulæ

$$\left.\begin{aligned} x&=at+a'u,\\ y&=bt+b'u,\\ z&=ct+c'u, \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots \quad (3)$$

in which t and u are absolutely indeterminate integral numbers; but if the condition (2) be not satisfied, the formulæ (3) will not represent *all*, but only *some* of the solutions of the equation (1). If, therefore, by any method, as for example that of Euler, we have arrived at formulæ of the type of the formulæ (3), which demonstrably contain the complete solution of the indeterminate equation, we may be certain that the three numbers analogous to the numbers (2) admit of no common divisor. Thus, by applying Euler's method of solution, which is explained in most books of algebra, to the indeterminate equation $Ax+By+Cz=0$, we obtain the solution of a celebrated problem, first considered by Gauss in the 'Disquisitiones Arithmeticæ,' of which the following is the enunciation.

"Given 3 numbers A, B, C, to find six others,

$$\text{such that} \qquad \begin{matrix} a, b, c, \\ a', b', c', \end{matrix}$$

$$A=bc'-b'c, \quad B=ca'-ac', \quad C=ab'-a'b."$$

Other methods more symmetrical, and perhaps not more tedious than that of Euler, were also suggested in this paper for the treatment of indeterminate equations, and for the resolution of an important class of arithmetical problems which depend on those equations in the manner just explained.

On a Generalization of Poncelot's *Theorems for the Linear Representation of Quadratic Radicals. By* Professor SYLVESTER, *M.A., F.R.S.*

The author explained the application of Poncelet's theorems, to practical questions of mechanics in the case of forces acting in a single plane as in the theory of bridges.

He next referred to the mode of extension of this theorem, suggested by Poncelet, applicable to the case of forces in space, and pointed out its insufficiency, and, in a certain sense, its incorrectness.

The essential preliminary question to be resolved in the first instance (after which the matter became one of easy calculation), was shown to be that of cutting off by a plane the smallest possible segment of a sphere that should contain the whole of a given set of points lying on the sphere's surface. Some years ago Prof. Sylvester had proposed in the 'Quarterly Mathematical Journal,' without any suspicion of its having any practical applications, the following question :—"Given a set of points in a plane to draw the smallest possible circle that should contain them all." By a singular coincidence, Professor Pierce, of Cambridge University, U.S., had studied this question and obtained a complete solution of it, which he had communicated to the author during the present meeting of the British Association. A slight consideration served to show that precisely the same solution as Professor Pierce had found for the problem of points in a plane was applicable with a merely nominal change to the sphere also; and thus the solution of a question set almost in sport was found to supply an essential link for the complete development of a method of considerable importance in practical mechanics. The author stated that it would be easy to draw up tables of the values of the constants appearing in the linear function, representing the resultant of three forces at right angles to one another, for the principal cases likely to occur in practice, the values of these constants depending solely upon the condition of relative magnitude to which the component forces are supposed to be subjected.

LIGHT, HEAT.

On the Influence of very small Apertures on Telescopic Vision. By Sir DAVID BREWSTER, *K.H., F.R.S.*

[The manuscript of this paper has been lost.]

On some Optical Illusions connected with the Inversion of Perspective. By Sir DAVID BREWSTER, *K.H., F.R.S.*

The term "Inversion of Perspective" has been applied to a class of optical illusions, well known and easily explained, in which depressions are turned into elevations, and elevations into depressions. One of the most remarkable cases of this kind, which has not yet been explained, presented itself to the late Lady Georgiana Wolf, and has been recorded by her husband Dr. Wolf. When she was riding on a sand-beach in Egypt, all the footprints of horses appeared as elevations, in place of depressions, in the sand. No particulars are mentioned, in reference to the place of the sun, or the nature of the surrounding objects, to enable us to form any conjecture respecting the cause of this phenomenon. Having often tried to see this illusion, I was some time ago so fortunate as not only to observe it myself, but to show it to others. In walking along the west sands of St. Andrews, the footprints, both of men and of horses, appeared as elevations. In a short time they sank into depressions, and subsequently rose into elevations. The sun was at this time not very far from the horizon, on the right hand; and on the left there were large waves of the sea breaking into very bright foam. The only explanation which occurred to me was, that the illusion appeared when the observer supposed that the footprints were illuminated with the light of the breakers, and not by the sun. Having, however, more recently observed the phenomenon, when the sun was very high on the right, and the breakers on the left very distant, and consequently very faint, I could not consider the preceding explanation as well-founded. Upon attending to the circumstances under which they were now seen, I observed that the human footprints were all covered with dry sand that had been blown into them, so that they were much brighter than the surrounding sand, and than the dark side of the impression next the sun; and hence it is probable that they appeared to be nearer the eye than the dark sand in which they were formed, and consequently elevations. After repeated examinations of them, I found the footprints appeared as elevations as far as the eye could see them; and they were equally visible with one or both eyes. But whenever the eye rested for a little while on the nearest footprint, it resumed its natural concavity.

I have observed other illusions of this kind, which are more easily explained, though they differ from any hitherto described. In the Church of Saint Agostino in Rome, there is above each arch a painted festoon suspended on two short pillars; but instead of appearing in relief, as the painter intended, by shading the one side of them, they appeared concave, like an intaglio. In other positions in the church they rose into relief. Upon a subsequent visit to the church, I found that the festoon, or suspended wreath, was concave when it was illuminated, or rather when the observer saw that it was illuminated, by a window beneath it, and in relief when the eye saw that it was illuminated by a window above it, the object being similarly illuminated in both cases. In the common cases of inverted perspective, the eye is deceived by looking at the inversion of the shadow in the cameo or intaglio itself; but in the present case the eye is deceived by perceiving that the body painted, supposed to be in relief, is illuminated by a light either above or below it.

An optical illusion of a different kind presented itself to me in the Church of Santa Giustina at Padua. Upon entering the church we see three cupolas. The one beneath which we stood appeared very shallow; the next appeared much deeper, and the third deeper still. They were all, however, of the same depth, as we ascertained by placing ourselves under each in succession, and observing that it was always the shallowest.

On Microscopic Vision, and a New Form of Microscope.

By Sir DAVID BREWSTER, *K.H., F.R.S.*

In studying the influence of aperture on the images of bodies as formed in the camera, by lenses or mirrors, it occurred to me that in microscopic vision it might exercise a still more injurious influence. Opticians have recently exerted their skill in producing achromatic object-glasses for the microscope with large angles of aperture. In 1848 the late distinguished optician, Mr. Andrew Ross, asserted "that 135° was the largest angular pencil that could be passed through a microscopic object-glass," and yet in 1855 he had increased it to 170°! while some observers speak of angular apertures of 175°. In considering the influence of aperture, we shall suppose that an achromatic object-glass with an angle of aperture of 170° is optically perfect, representing every object without colour and without spherical aberration. When the microscopic object is a cube, we shall see five of its faces; and when it is a sphere or a cylinder, we shall see nine-tenths or more of its circumference. How then does it happen that large apertures exhibit objects which are not seen when small apertures with the same focal length are employed? This superiority is particularly shown with test-objects marked with grooves or ridges, and obliquely illuminated. The marginal part of the lens will enlarge the grooves and ridges, and they will thus be rendered visible, not because they are seen more distinctly, but because they are expanded by the combination of their incoincident images. Hence we have an explanation of the fact—well known to all who use the microscope,—that objects are seen more distinctly with object-glasses of small angular aperture. In the one case we have, with the same magnifying power, not only an enlarged and indistinct image of objects, but a false representation of them, from which their true structure cannot be discovered; while in the other we have a smaller and distinct image, and a more correct representation of the object.

But these are not the only objections to large angular apertures and short focal lengths. 1. In the first place, it is extremely difficult to illuminate objects when so close to the object-glass. 2. There is a great loss of light, from its oblique incidence on the surface of the first lens. 3. The surface of glass,—with the most perfect polish,—must be covered with minute pores, produced by the attrition of the polishing powder; and light, falling upon the sides of these pores with extreme obliquity, must not only suffer diffraction, but be refracted less perfectly than when incident at a less angle. 4. When the object is almost in contact with the anterior lens, the microscope is wholly unfit for researches in which mechanical or chemical operations are required, and also for the examination of objects enclosed in minerals or other transparent bodies. 5. In object-glasses now in use, the rays of light must pass through a great thickness of glass of doubtful homogeneity. It is a question yet to be solved whether or not a substance can be truly transparent, —in which the elements are not united in definite proportion,—in which the substances combined have very different refractive and dispersive powers; and in which the particles are so loosely united that they separate from one another, as in the various kinds of decomposition to which glass is liable.

If the best microscopes are affected by these sources of error, every exertion should be made to diminish or remove them. 1. The first step, we conceive, is to abandon large angular apertures, and to use object-glasses of moderate focal length, effecting at the eye-glass any additional magnifying power that may be required. 2. In order to obtain a better illumination, either by light incident vertically or obliquely, a new form of the microscope would be advantageous. In place of directing the microscope to the object itself, placed as it now is almost touching the object-glass, let it be directed to an image of the object, formed by the thinnest achromatic lens, of such a focal length that the object may be an inch or more from the lens, and its image equal to, or greater, or less than the object. In this way the observer will be able to illuminate the object, whether opake or transparent, and may subject it to any experiments he may desire to make upon it. It may thus be studied without a covering of glass, and when its parts are developed by immersion in a fluid. 3. The sources of error arising from the want of perfect polish and perfect homogeneity of the glass of which the lenses are composed, are, to some extent, hypothetical; but there are reasons for believing,—and these reasons corroborated by facts,—that a body whose ingredients are united by fusion, and kept in a state of constraint from which they are striving to get free, cannot possess that homogeneity of structure, or that perfection of polish, which will allow the rays of light to be refracted and transmitted without injurious modifications. If glass is to be used for the lenses of microscopes, long and careful annealing should be adopted, and the polishing process should be continued long after it appears perfect to the optician. We believe, however, that the time is not distant when transparent minerals, in which their elements are united in definite proportions, will be substituted for glass. Diamond, topaz, and rock-crystal are those which appear best suited for lenses. The white topaz of New Holland is particularly fitted for optical purposes, as its double refraction may be removed by cutting it in plates perpendicular to one of its optical axes. In rock-crystal the structure is, generally speaking, less perfect along the axis of double refraction than in any other direction, but this imperfection does not exist in topaz.

On the decomposed Glass found at Nineveh and other places.

By Sir David Brewster, *K.H., F.R.S.*

The different kinds of glass which are in common use, consist of sand or silex combined by fusion with earths or alkalies, or metals which either act as fluxes, or communicate different colours or different degrees of lustre or refractive power to the combination.

In quartz or rock-crystal, which is pure silex, and in other regularly crystallized bodies, the molecules or atoms unite in virtue of regular laws, the pole of one atom uniting with the pole of another. Such substances, therefore, do not decompose under the ordinary action of the elements. The lens of *Rock-Crystal*, for example, found by Mr. Layard at Nineveh, is as sound as it was many thousand years ago when in the form of a crystal.

In the case of glass, however, the silex has been melted and forced into union with other bodies to which it has no natural affinity; and therefore its atoms, which have their similar poles lying in every possible direction, have a constant tendency to recover their crystalline position as when in a state of silex. For the same reason, the earths, alkalies and metals, with which the atoms of silex have been constrained by fusion to enter into union, all tend to resume their crystalline position and separate themselves from the silex.

Owing to the manner in which melted glass is cooled and annealed, whether it is made by flashing or blowing, or moulding, the cohesion of its parts is not the same throughout the mass; and consequently its particles are held together with different degrees of force, varying in relation to points, lines, and surfaces. An atom of the flux, or other ingredient, may be less firmly united to an atom of silex in one place than in another, depending on the degree of heat by which they were combined, or upon the relative positions of the poles of the atoms themselves when combined. There are some remarkable cases where flint-glass without any rude exposure to the elements has become opake, and I have seen specimens in which the disintegration had commenced a few years after it was made. In general, however, the process is very slow, excepting in stables, where the prevalence of ammonia hastens the decomposition and produces all the beautiful colours of the soap-bubble. It is, however, from among the ruins of ancient buildings that glass is found in all the stages of decomposition; and there is perhaps no material body that ceases to exist with such grace and beauty, when it surrenders itself to time and not to disease.

In damp localities, where acids and alkalies prevail in the soil, the glass rots as it were by a process which, owing to the opacity of the rotten part, it is difficult to study. It may be broken between the fingers of an infant; and we often find in the middle of the fragment a plate of the original glass which has not yielded to the process of decay.

In dry localities, where Roman, Greek, and Assyrian glass has been found, the process of decomposition is exceedingly interesting, and its results singularly beautiful. At one or more points in the surface of the glass the decomposition begins.

It extends round that point in spherical surfaces so that the first film is a minute hemispherical cup of exceeding thinness. Film after film is formed in a similar manner, till perhaps twenty or thirty are crowded into the 50th of an inch. They now resemble the section of a pearl or of an onion, and as the films are still glass, the colours of thin plates are seen when we look down through their edges which form the surface of the glass. These thin edges, however, being exposed to the elements, suffer decomposition. The particles of silex and the other ingredients now readily separate, and the decomposition goes on downwards in films parallel to the surface of the glass, the crystals of silex in one specimen forming a white ring, and the other ingredients rings of a different colour. (See the Figure.)

Such is the process round one point, but the decomposition commences at many points, and generally these points lie in lines, so that the circles of decomposition meet one another and form sinuous lines. When there are only two points, these circles, when they meet, surround the two points of decomposition like the rings round two knots of wood; and in like manner, when there are many points, and these points near each other, the curves of decomposition unite as already mentioned, and form sinuous lines. When the decomposition is uniform and the little hemispheres have nearly the same depth, we can separate the upper film from the one below it, the convexities of the one falling into the concavities of the other.

This general description was illustrated by drawings on the table, all of which were executed by Miss Mary King, of Ballylin, now the Hon. Mrs. Ward.

But beautiful and correct as these drawings are, they convey a very imperfect idea of the brilliant colours and singular forms which characterize glass in a particular stage of its decomposition, and of the optical phenomena which it exhibits in common and polarized light.

When the decomposition has gone regularly on round a single point, and there is no other change, a division of the glass into a number of hemispherical films within one another takes place, the group of films exhibiting in the microscope circular cavities, which under different circumstances become elliptical and polygonal.

In salt water the decomposition of glass goes on more rapidly, as I have found in examining one of the bottles brought up in the wreck of the 'Royal George;' and the same effect may be produced by a quicker process. M. Brame*, of Paris, having seen a notice of the decomposed glass from Nineveh which I read at the Association some years ago, succeeded in producing, in a very short time, regular and irregular circles of decomposition, in the centre of which there was always a small cavity or nucleus. This effect was obtained by immersing fragments of thick glass in a mixture of fluoride of calcium and concentrated sulphuric acid, or by exposing them to the action of the vapour of fluorhydrique acid.

Such are some of the general phenomena of decomposed glass when seen by light reflected from its exposed surfaces; but when we separate the films and examine them in the microscope, either by common or polarized light, a series of phenomena are seen of the most beautiful kind,—so various and so singular that it would be a vain attempt to describe them. A general idea of them, however, may be obtained from the drawings, and from a description of three varieties of these films.

I. The first of these varieties has rough surfaces,—the roughness arising from an almost infinite number of hemispherical *cavities* on one side of the film, and hemispherical *convexities* on the other side. When these cavities are separated by flat portions of the film, they are perfectly *circular*; but when they are crowded together, they are irregularly *polygonal*, the sides of the polygons forming a sort of network, the cavities or convexities forming the meshes of the net.

The convex and concave surfaces are not rough but specular, and reflect and transmit white light, exhibiting none of the colours of thin plates.

In polarized light, each of the cavities, whether circular or polygonal, act as negative uniaxal crystals, exhibiting by the interference of the refracted and transmitted pencils the black cross, and the *white of the first order* in Newton's scale, rising sometimes to *yellow* or falling to the *palest blue*, or disappearing altogether, according to the number or curvature of the films which compose it.

II. The second variety of these films has perfectly specular surfaces, in consequence of having almost no cavities. They exhibit in common light, and in a very beautiful manner, the colours of thin plates, the *transmitted* being complementary to the *reflected* light. This variety is exceedingly rare. In a specimen on the table the *reflected* light is *blue* and the transmitted *yellow*. In some of the fragments a few insulated circular cavities with the black cross occur, the tints which surround it being modified by the general tint of the film.

III. The third variety of decomposed glass consists of films containing cavities of all sizes and forms, from the 30th of an inch to such a size that they are hardly visible by the microscope, giving to the film which they compose a sort of stippled appearance, or an imperfectly specular surface.

These cavities or combinations of hemispherical films are *circular*, *elliptical*, or *irregularly polygonal*. The colours which they reflect and transmit are complementary, and the tints and rings which in polarized light surround the black cross are curiously modified by the general tint of the fragment, and the curvature of its component films,—the black cross itself varying its shape with the form of the cavities. When the cavities are flat, the black cross disappears as in thin slices of uniaxal crystals; but the tints reappear, rising to higher orders by inclining the plate.

The cavities are often arranged in sinuous curves, and encroach upon one another, so that the polarized tints appear only at the margin of the line which they form. They frequently run in perfectly straight lines, and when they are very small and invisible as cavities, their margins form in polarized light brilliant lines, which are often grouped in bands like the stripes in a ribbon. Sometimes they are only a few thousands of an inch in diameter, and might be used as micrometers in the microscope, every trace of the cavities which form them having disappeared. These lines of polarized light all disappear when they lie in the plane of polarization of the incident light, or perpendicular to that plane.

In some specimens a decomposition has taken place on several points of the convex or concave surfaces of the cavities, so as to form new cavities; and each of these minute cavities, often ten or twelve in number, exhibit the black cross with its tints, but disfiguring, of course, those of the cavity upon which they have encroached.

In the three varieties of decomposed glass which I have described, the films are pure glass,—deriving their colour from the individual films of which they are composed. This is obvious from the fact of their becoming colourless by a sufficient inclination of the plates, and also by the introduction of a drop of water or alcohol. When the fluid has evaporated, the films recover their original colour; and though a film of fluid has separated each of the almost infinitesimal layers of the glass, yet they adhere as firmly as ever after the fluid has evaporated. If an oil or balsam is introduced, it passes slowly and unequally between the layers, so that the retreating colour is bounded by a spectrum of the various tints which the film combines.

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* Comptes Rendus, &c., Nov. 2, 1852.

But though the films themselves are glass, yet I have often found between them beautiful circular crystals of *silex*, which are finely seen in polarized light, and exhibit many of the regular and irregular forms which I have represented in a paper on Circular Crystals lately published in the 'Transactions of the Royal Society of Edinburgh.' They are sometimes *dendritic*, and assume, round the black cross, foliated shapes like the leaves of plants. At other times, but very rarely, they occur in circular groups,—related to a crystal of silex in their centre. One of these groups is so remarkable as to merit particular notice. Around a minute speck of silex there is formed, at a considerable distance from it, a circular band of equally minute crystalline specks, and at a greater distance a *second* circular band concentric with the first, and consisting of still smaller siliceous particles, hardly visible in the microscope. By what atomic force, or by what other cause, the central crystal has placed its attendant crystals in regular circles around it, remains to be discovered. I have already described a similar phenomenon, as produced during the formation of circular crystals under constraint, and when crystallizing freely; but I am not aware that any other person has either seen the phenomenon or attempted to explain it.

The films of decomposed glass, as I have long ago shown, absorb definite rays of the spectrum like coloured media. They change, in the most distinct manner, the colours of different parts of the spectrum, and frequently insulate bands of purely white light, in or near its most luminous division.

[*The drawings referred to in this commnnication were laid before the Section, and some of the specimens of decomposed glass were exhibited in the Museum in the course of the evening.*]

On his own Perception of Colours. *By* J. H. GLADSTONE, *Ph.D., F.R.S.*

The author described himself as in an intermediate position between those who have a normal vision of colours, and those who are termed "colour-blind." These latter are usually unacquainted with the sensations of either red or green, and it becomes a desideratum to have good observations on those who are capable of acting somewhat as interpreters between them, and those who perceive every colour. By means of Chevreul's chromatic circles and scales, Maxwell's colour-top, coloured beads, &c., the author was able to determine the following points in respect to his own vision. He sees red, in all probability, like other people, but it requires a larger quantity of the colour to give the sensation than is usually the case; hence a purple appears to him more blue, and an orange more yellow, than to the generality of observers. He is perfectly sensible of green, or rather of two distinct greens, the one yellowish, the other bluish; but between them there lies a particular shade of green, to which his eyes are insensible as a colour. This modifies his perception of many greens that approximate to what is to him invisible. The shade occurs in nature on the back of the leaf of the variegated holly, and it may be produced in Maxwell's top by certain combinations of the coloured disc; the simplest being

$$94{\cdot}5 \text{ Brunswick Green (Blue Shade)} + 5{\cdot}5 \text{ Ultramarine} = 94 \text{ Black} + 6 \text{ White}.$$

He finds that this shade, though invisible to him as green, is yet capable of neutralizing red when viewed simultaneously, but it does not neutralize so much red with him as with observers of ordinary vision.

While able perfectly to distinguish between red and green, the contrast does not readily catch his eye, especially at a distance; in fact, he is somewhat short-sighted in respect to these colours. He has reason to believe that, in his case, there has been a gradual improvement in his actual perception of colours, independently of his greater knowledge of them, though this is in opposition to the general experience of those whose vision is in any way abnormal, and no other instance was known to the late Prof. George Wilson, whose book is the standard one on the subject of colour-blindness.

On the Chromatic Properties of the Electric Light of Mercury.

By J. H. Gladstone, *Ph.D., F.R.S.*

While examining the brilliant electric light produced in an interrupted current of mercury in the apparatus contrived by Professor Way, the author was struck by the strange manner in which it modified the apparent colours of surrounding objects, and especially with the ghastly purple and green hues which it imparted to the faces and hands of the spectators. This led him to an investigation of the subject, and a prismatic analysis of the light itself. Chevreul's "cercles chromatiques" showed yellow, green, and blue distinctly, but very little red, while the violet became remarkably luminous. The modifications of colour in many bodies of known composition were then related, as for instance the green sulphate of iron which appeared colourless, and the scarlet iodide of mercury which assumed a brownish metallic appearance. Substances capable of fluorescing exhibited that phenomenon with remarkable beauty. On analysing this light by means of a refractive goniometer, the author found it to consist of a great number of separate rays, and not to present in any part a continuous band of light. This was exhibited by means of a diagram in coloured chalks on black paper, by the side of a solar prismatic spectrum. The position of the different rays had been measured, and their relative intensity determined. There are red and orange rays, but they are of the most feeble intensity; some yellow rays of great brilliancy; two bright green rays; one blue ray of great luminosity; and a number of violet rays. One of these latter is situated far beyond the limits of the visible solar spectrum, in fact at about Becquerel's line N, and was bright to the eye, although it had passed through several pieces of glass—a medium that does not easily transmit the extra-violet rays. Its colour appeared to differ considerably according to its intensity, but might be described generally as a red-violet. The prismatic analysis explained fully the changes that red substances undergo when exposed to it—sometimes to brown, and at other times to purple, green, or whatever other colour in addition to red is principally reflected by them: it also explained all the other chromatic phenomena. Professor Wheatstone in 1835 described the spectrum of the electric light of mercury as containing seven definite rays; and Angström has recently given a drawing of the lines that coincides closely with the observations of the author on the more luminous rays, and shows that the Swedish physicist had not seen the extra violet lines. From his figures also it appears that the air is excluded from the luminous cone of mercurial vapour in Way's apparatus.

On a New Instrument for determining the Plane of Polarization.

By the Rev. Professor Jellett.

Professor Jellett described to the Section a new analysing prism, by which the plane of polarization of polarized light may be determined with great precision. This instrument consists of a long prism of calc-spar, which is reduced to the form of a right prism by grinding off its ends, and sliced lengthwise by a plane nearly but not quite perpendicular to its principal plane. The parts into which the prism is thus divided are joined in reversed positions, and a diaphragm with a circular opening is placed at each end. The light which passes through both diaphragms produces a circular field divided by a diametral slit into two parts, in which the planes of polarization are slightly inclined to one another. If then light which has been previously plane polarized be transmitted, it will be extinguished in the two parts of the field of view in positions which lie close together, and the light will become uniform in a position midway between these. This position determines the plane in which the incident light was polarized, with a precision much greater than has been otherwise attained. Professor Jellett stated that the different observations did not differ from one another by an angle greater than a minute, and that the instrument was equally applicable to the case of homogeneous light.

Note on the Caustics produced by Reflexion.
By L. L. Lindelöf, *Professor at Helsingfors.*

There are, no doubt, few branches of mathematical physics that have been more often discussed than the reflexion and refraction of light, and the theory of these phenomena has consequently been gradually reduced to the greatest simplicity. The whole doctrine of catoptrics and dioptrics may indeed be said to be implicitly contained in the elegant principle successively developed by Dupin, Quetelet, and Gorgonne, namely, that a system of rays that can be cut orthogonally by a particular surface, preserves this property after any number of reflexions and refractions. Nevertheless, it appears to me that the theory of caustics has been somewhat neglected. Not but what there are many interesting researches on this subject that have been conducted with abundance of care, but because these, for the most part, refer to certain very restricted cases, as for example, to reflecting surfaces of a particular kind. In examining from a somewhat more general point of view the theory of caustics produced by reflexion, I have arrived at certain results, which appear to me to be sufficiently curious to deserve a short notice.

I suppose the reflecting surface to be of any kind whatever, and that it is illuminated by a bundle of parallel rays. Suppose, now, that two of these rays impinge on the surface at two points A and A′ infinitely near each other. Unless certain particular conditions are fulfilled, the corresponding reflected rays will not be in the same plane. In order, therefore, that the two rays may meet after reflexion so as to form a point in a caustic, the points A and A′ must be related in a certain manner. Now it will be found that, starting from any point A, there will always be two different directions in which the consecutive reflected rays intersect, and by following these directions from point to point, certain curves will be traced on the surface, which play an important part in the theory of caustics, and which may be called *catoptrical lines.* These lines bear some analogy to the lines of greatest and least curvature, with which they sometimes coincide. Their form and situation depend not only on the nature of the surface, but also on the direction of the incident rays. Each point of the surface is the intersection of two catoptrical lines, which possess the remarkable property that their projections on the plane perpendicular to the incident rays, cut each other at right angles. To each catoptrical line there is a corresponding caustic formed by the rays reflected from the catoptric, and these caustic lines themselves form a *caustic surface,* which in general consists of two sheets, corresponding to the two systems of catoptrical lines.

Let x, y, and z be the coordinates of any point in the reflecting surface, and let the axis of z be parallel to the incident rays. Calling, as usual, the partial differential coefficients of z with respect to x and y of the first order p and q, those of the second r, s, and t, we have for the catoptrical lines the simple equation

$$dp\,.\,dy=dq\,.\,dr,$$

which may be put in the form

$$\left.\frac{dy}{dx}\right\rceil+\frac{r-t}{s}\frac{dy}{dx}-1=0;$$

since $dp=rdx+sdy$, $dq=sdx+tdy$.

The quantities p, q, r, s, and t being all expressible in terms of x and y by means of the equation to the reflecting surface, the two values of $\frac{dy}{dx}$ derived from the above equation can also be expressed in terms of x and y. If this differential equation can be integrated, the resulting relation between x and y, together with the equation to the surface, determine the catoptrical lines.

The point ξ, η, and ζ of the caustic corresponding to x, y, z of the reflecting surface, is determined by the following equations:—

$$\frac{\xi-x}{2p}=\frac{q-y}{2q}=\frac{\zeta\quad z-}{p^2+q^2-1}=\frac{t-s\frac{dy}{dx}}{2\,(s^2-rt)}.$$

Eliminating x, y, z by means of these three equations and that of the given surfaces, we obviously get the equation to the caustic surface; and eliminating the same quantities between the same three equations, and the two equations of any catoptrical line, we get the equations to the corresponding caustic line.

As to the application of this theory it offers no difficulty. On directing my attention more particularly to surfaces of the second order, I obtained the following results :—

(1) In the case of a sphere illuminated by parallel rays, the first system of catoptrical lines consists of great circles passing through the same point, the second of small circles cutting the former at right angles. The equation to the caustic surface that corresponds to the first system is

$$[4(\xi^2+\eta^2+\zeta^2)-a^2]^3=27a^4(\xi^2+\eta^2),$$

a being the radius of the sphere, while the second system has for its caustic a straight line passing through the centre of the sphere.

(2) If the reflecting surface be an ellipsoid or a hyperboloid, either of one or of two sheets, and the incident rays are parallel to one of the axes, the projections of the catoptrical lines on the plane of the other axes are either ellipses or hyperbolas, whose foci coincide with those of the section of the surface by the same plane.

(3) In the case of an elliptic paraboloid illuminated by rays parallel to its axis, the catoptrical lines form parabolas whose planes are parallel to one or the other of the principal sections of the surface. The caustic surface is reduced to two parabolas lying in the planes of the principal sections, and having the axis of the paraboloid for their common axis, but situated in opposite directions. That which lies in the plane of the greatest of the principal sections is turned in the same way as the paraboloid, that lying in the perpendicular plane is turned in the opposite direction. Each of these parabolas has the same focus as the principal section to which it is perpendicular, and a parameter equal to the difference of the parameters of the principal sections. Lastly, each of these caustic lines is perpendicular to the corresponding system of catoptrical lines.

(4) In the case of a hyperbolic paraboloid illuminated by rays parallel to its axis, the catoptrical lines also form two systems of parabolas in planes parallel to the planes of the principal sections, and the caustic is again reduced to two parabolas situated in the same two planes, and turned in opposite directions, each having a parameter equal to the *sum* of the parameters of the two principal sections.

There would be no difficulty in applying the above formulæ to surfaces of revolution, to cylindrical conical developable surfaces, &c., but the preceding will suffice to give an idea of the results that may be deduced in certain cases.

On the Results of Bernoulli's *Theory of Gases as applied to their Internal Friction, their Diffusion, and their Conductivity for Heat. By* Professor MAXWELL, *F.R.S.E.*

The substance of this paper is to be found in the 'Philosophical Magazine' for January and July 1860. Assuming that the elasticity of gases can be accounted for by the impact of their particles against the sides of the containing vessel, the laws of motion of an immense number of very small elastic particles impinging on each other, are deduced from mathematical principles; and it is shown,—1st, that the velocities of the particles vary from 0 to ∞, but that the number at any instant having velocities between given limits follows a law similar in its expression to that of the distribution of errors according to the theory of the "Method of least squares." 2nd. That the relative velocities of particles of two different systems are distributed according to a similar law, and that the mean relative velocity is the square root of the sum of the squares of the two mean velocities. 3rd. That the pressure is one-third of the density multiplied by the mean square of the velocity. 4th. That the mean *vis viva* of a particle is the same in each of two systems in contact, and that temperature may be represented by the *vis viva* of a particle, so that at equal temperatures and pressures, equal volumes of different gases must contain equal numbers of particles. 5th. That when layers of gas have a motion of sliding over each other, particles will be projected from one layer into another, and thus tend to resist the sliding motion. The amount of this will depend on the average distance described by a particle between successive collisions. From the coefficient of friction in air, as given by Professor Stokes, it would appear that this distance is $\frac{1}{447000}$ inch; the mean velocity being 1505 feet per second, so that each particle makes 8,077,200,000 collisions per second. 6th. That diffusion of gases is due partly to the agitation of the particles tending to mix them, and partly to the existence of opposing currents of the two gases through each other. From experiments of Graham on the diffusion of olefiant gas into air, the value of the distance described by a particle between successive collisions is found to be $\frac{1}{389000}$ of an inch, agreeing with the value derived from friction as closely as rough experiments of this kind will permit. 7th. That conduction of heat consists in the propagation of the motion of agitation from one part of the system to another, and may be calculated when we know the nature of the motion. Taking $\frac{1}{400000}$ of an inch as a probable value of the distance that a particle moves between successive collisions, it appears that the quantity of heat transmitted through a stratum of air by conduction would be $\frac{1}{10,000,000}$ of that transmitted by a stratum of copper of equal thickness, the difference of the temperatures of the two sides being the same in both cases. This shows that the observed low conductivity of air is no objection to the theory, but a result of it. 8th. That if the collisions produce rotation of the particles at all, the *vis viva* of rotation will be equal to that of translation. This relation would make the ratio of specific heat at constant pressure to that at constant volume to be $1{\cdot}\dot{3}\dot{3}$, whereas we know that for air it is 1·408. This result of the dynamical theory, being at variance with experiment, overturns the whole hypothesis, however satisfactory the other results may be.

On an Instrument for Exhibiting any Mixture of the Colours of the Spectrum. By Professor MAXWELL, *F.R.S.E.*

This instrument consists of a box about 40 inches long by 11 broad and 4 deep. Light is admitted at one end through a system of three slits, of which the position and breadth can be altered and accurately measured. This light, near the other end of the box, falls on two prisms in succession, and then on a concave mirror, which reflects it back through the prisms, so as to increase the dispersion of colours. The light then falls on a plane mirror inclined 45° to the axis of the instrument, and is reflected on a screen in which is a narrow slit. On this screen are formed three pure spectra, the position and intensity of each depending on the position and breadth of the slit through which the light was admitted. The portions of these spectra which fall on the slit in the screen pass through, and are viewed by the eye placed close behind it. A colour compounded of these three portions of three different spectra is seen illuminating the prisms, and can be compared with white reflected light seen past the edge of the prisms. The advantage of the instrument over that described to the Association in 1859 is, that by the principle of reflexion the rays return in the same tube, so as not to require two limbs forming an awkward angle; while at the same time, by doubling the dispersion, the necessary length of the instrument is diminished. By means of this instrument many observations of colours have been taken. Some of these by a colour-blind person are published in the 'Philosophical Transactions' for 1860.

Further Researches regarding the Laws of Chromatic Dispersion. By MUNGO PONTON.

In this paper the author has revised, and improved in its details, his method of expressing the refractive index of a medium as a function of the wave-length.

He employs λ to denote the *ratio* of any particular wave-length referred to that of the fixed line B as unity. The numerical values of the wave-lengths of the lines C, D, E, F, G, H are given, as calculated from Fraunhofer's measures.

The author's formula for expressing the refractive index (μ) as a function of λ is

$$\mu=\frac{\lambda^n}{\frac{\lambda^n}{\epsilon_n}-a_n},$$

where n must be found by the method of trial and error for each medium in particular, and ϵ^n, a^n are certain known functions of n and of the observed indices.

Thus the formula contains three arbitrary constants, which must be determined from the results of observation.

When these constants are properly determined for any medium, the formula, even in the case of the most highly dispersive media which have been observed, is found to represent very accurately the observations, the utmost error being only a few units in the fourth place of decimals.

Experiments and Conclusions on Binocular Vision.
By Professor William B. Rogers, *Boston, U.S.*

The following experiments, intended to test the theory of the successive combination of corresponding points in stereoscopic vision, are I believe in part new, and are in part modified repetitions of experiments already described by Professor Wheatstone and Professor Dove.

1. Let two slightly inclined luminous lines, formed by narrow slits in a strip of black card-board, be combined into a perspective line, either with or without a stereoscope. Looking at this for a few seconds, so as to induce the reverse ocular spectrum, and then directing the eyes towards the opposite wall of the apartment, a single spectrum will be observed having the attitude and relief of the original binocular resultant.

As a strong illumination of the lines is necessary to bring out the full effect, the card-board should be held between the eyes and some brilliantly white surface, as the globe of a solar lamp or a strongly illuminated cloud, care being taken to prevent the entrance of extraneous light.

2. Using the same arrangement, let the luminous lines be regarded *in succession* each by the corresponding eye, the other eye being shaded so that no direct binocular combination can be formed. On looking towards the wall, it will be seen that *the two subjective images unite to form a single spectral line, having the same relief as if the lines had been directly combined* by simultaneous vision, either with or without a stereoscope.

While the perspective image continues distinctly visible, let either eye be closed, the other being still directed towards the wall. The image will instantly lose its relief and take its position on the plane of the wall as an inclined line, corresponding to the subjective image in the eye that has remained open. When the subjective impressions have been sufficiently strong, it is easy to alternate these effects, by projecting first the picture proper to the right eye, then that of the left, on the plane of the wall, with their respective contrary inclinations; and then looking with both eyes, we see the resultant image start forth in its perspective attitude.

It is hardly necessary to say that to obtain these effects satisfactorily the lines should be very strongly illuminated, and the observer should have some practice in experiments on subjective vision. Under these conditions I have found the results to be *perfectly certain and uniform.*

In these experiments, according to the theory of Sir David Brewster, the resultant spectrum, instead of being a single line in a perspective position, ought to present the form of two lines inclined or crossing, situated in the plane of the wall without projection or relief. The conditions of the experiments are such as to exclude all opportunity of *a shifting of the image on the retina,* and such shifting is obviously essential to the successive combination of pairs of points required by the theory in the production of perspective effect.

In reference to the first experiment, it might perhaps be maintained that, as the perspectiveness of the original resultant on which the eyes were converged formed part of the direct perception in first combining the lines, it would be likely through association to be included also in the spectral or subjective perception. But this consideration, which at best appears to me of little weight, is entirely inapplicable to the conditions of the second experiment. For here the eyes are in the first place impressed *in succession* with their respective images, and are not allowed to see the resultant; and yet when they are together directed to the wall, *the perception of the single perspective resultant is at once originated.*

3. Without resorting to these troublesome efforts of subjective vision, the following experiment furnishes, as I think, conclusive proof that pictures successively impressed on the respective eyes are sufficient for the stereoscopic effect.

Let an opake screen be made to vibrate or revolve somewhat rapidly between the eyes and the twin pictures of a stereoscopic drawing, so as alternately to expose and cover each, while it completely excludes the simultaneous vision of any parts of the two. The *stereoscopic relief will be as apparent in these conditions as when the moving screen is withdrawn.* Here at each moment the actual impression in the one eye and the retained impression in the other, form the elements of the perspective resultant perceived.

It seems clearly inferrible from these experiments, that the perception of the resultant in its proper relief does not require that each pair of corresponding points should be combined by directing the optic axes to them pair by pair in succession, as has been maintained. Nor is it necessary for the singleness of the resultant perception, that the images of corresponding points of the object should fall on what are called corresponding points of the retinæ. The condition of single vision in such cases seems to be simply this, *that the pictures in the two eyes shall be such and so placed as to be identical with the pictures which the real object would form if placed at a given distance and in a given attitude before the eyes.*

4. I have of late years frequently repeated Dove's experiments with instantaneous illumination, leading, as is well known, to similar conclusions. In these I have found it most convenient to use the momentary bright flash of the Leyden bottle, connected with the Ruhmkorff coil according to Grove's plan. With a powerful coil of Ritchie's construction, and a brass disc 8 inches in diameter having the usual concentric striation, I am able, even with a single flash, to see the luminous line in perspective, and by a quick succession of flashes, I can have it as steadily before me as if illuminated by the sun.

A twin-drawing of a simple geometrical solid, placed in the stereoscope, and illuminated by the same means, appears single and in just relief in all cases where the flashes recur at short intervals, and very frequently presents the same appearance even with a single momentary light.

To be assured that the effect was not due to the *recollection* of a previous stereoscopic impression, I have caused slides to be introduced, of which the form could not be thus anticipated, and still have had no difficulty in describing the perspective resultant as exhibited by the instantaneous illumination.

5. *On the inability of the eyes to determine which retina is impressed.*—Let a small disc of white paper be fastened on a slip of black pasteboard of the size of a stereoscopic slide, and let this be so placed in the instrument as to bring the disc centrally in front of one of the glasses, the *person who is to view it being kept in ignorance of the position of the spot.* On looking into the instrument he will think he sees it with both eyes equally, and, without resorting to the expedient of closing his eyes alternately, will be *entirely unable to determine whether the spot is before his right eye or his left eye.* The spot appears to be placed in the mesial or binocular direction, and in the same position as that of the resultant image of two such discs, presented severally to the two eyes.

It may be concluded from this that the mere retinal impression on either eye is unaccompanied by any conscious reference to the special surface impressed, and that the visual perception belongs to that part of the optical apparatus near or within the brain, which belongs in common to both eyes.

This experiment is moreover interesting from its bearing on the *law of visible direction.* It shows that the sense of direction is just as truly normal to the central part of the retina that has received no light from the object, as to the part of the other retina upon which the white spot has been actually painted by the rays. In truth it is *normal to neither*, but is felt to be in the middle line between the two, that is, in the binocular direction. This experiment therefore contradicts the law, which assumes that the direction in which an object appears is always in the normal to the point of the retina impressed.

Régulateur Automatique de Lumière Electrique. *By* M. SERRIN.

To form the electric arch of light, it is first necessary to bring the charcoal points into contact, then gently to separate them by degrees, as they glow, afterwards to cause them to approach constantly, as they are wasted by use, carefully avoiding bringing them into contact. In order to keep the point of illumination fixed in space, each charcoal point must simultaneously approach the other, and that in the proportion in which each is wasted by use. In fine, for rendering the electric light useful, all these conditions must be self-produced with the utmost regularity, without any intervention of the human hand, that is to say, in a manner completely automatic; and this was the object the regulator was invented for. In a simple and easy manner, this apparatus, which may be compared to an extremely sensible balance, is composed of two mechanisms connected the one with the other, and yet independent; when one acts the other is in repose, and reciprocally. One of these consists of an oscillating system,—the chief feature of the regulator destined to produce the separation of the charcoal points, and also to determine their re-approach. The other mechanism, composed of wheel-work, has for its object to ensure the re-approach of the charcoal points in the proportion of their waste by use. The two port-carbons which carry the charcoal pieces are placed vertically one above the other. The superior is in connexion with the wheel-work, and is the positive electrode of the battery; the inferior depends as well on the wheel-work as on the oscillating system, and is the negative electrode. The superior port-carbon, by its weight, causes the inferior to ascend. The oscillating system forms a parallelogram, of which the angles are jointed, one of the vertical sides of which is suspended by a spring, and carries at its lower part a soft iron armature, placed over a horizontal electro-magnet. When the apparatus is in repose, the charcoals are in contact; on the contrary, they separate when the circuit is completed and the voltaic arc appears. As the wasting by use of the charcoals increases the length of the voltaic arc, the armature increases its distance from the electro-magnet, become less powerful, and the charcoals re-approach by a quantity frequently less than the one-hundredth of a millimetre; but according as they re-approach, the electro-magnet recovers its original power, the armature is attracted anew, and the charcoals stop until a new wasting gives rise to a new re-approach followed by a new stoppage, and so on in succession. In consequence of its extreme sensibility, it will work either with a voltaic pile or an electro-magnetic machine.

On some Recent Extensions of Prevost's *Theory of Exchanges.* *By* BALFOUR STEWART, *M.A.*

On Rings seen in viewing a Light through Fibrous Specimens of Calc-spar. *By* G. JOHNSTONE STONEY, *M.A., F.R.A.S. &c.*

The author mentioned that Sir David Brewster had drawn the attention of the Association, at the York meeting, to the beautiful display of four rings which may be seen on looking at a luminous point through fibrous specimens of calc-spar.

In the present communication the forms of the rings were traced as a consequence of Huygen's construction, and the points where rings vanish, or where irises pass into one another, were determined. The state of polarization was also examined, and the positions, in which two of the rings, which are faint, will be most conspicuous. The author drew particular attention to the great range of brightness of these faint rings, and to the circumstances attending the disappearance of one of them, in consequence of a curious case of impossible reflexion, as offering peculiar facilities for testing rival hypotheses.

On Thin Films of Decomposed Glass found near Oxford. *By* R. THOMAS.

The films were observed on bottles of the form called magnums, which had been lying in the Cherwell above a century. The films formed by decomposition on the surface were easily detached, and submitted to observation. The reflected and transmitted tints were complementary to each other when held perpendicularly; they varied when the position was changed and the path of the rays became oblique. By examination under the microscope the films were found to be composed of a series of still thinner films, several of which were required for manifesting colours by transmitted light. In some cases as many as sixteen of these thinner laminæ were counted. The colour is brightened in proportion to the number of laminæ. When two films overlap, the tint produced is the mixture of the two—yellow and blue, for instance, producing green. In general the layers are flat and the colour uniform, but sometimes undulated over bubbles, and then the colour is varied. Some specimens with a few bubbles show a difference of colour at the bubble with common light, and with polarized light the black cross and complementary colours appear.

ELECTRICITY, MAGNETISM.

On certain Results of Observations in the Observatory of His Highness the Rajah of Travancore. By JOHN ALLAN BROUN, *F.R.S.*

The following were noticed by the author. 1st. With regard to the mode in which the diurnal law of magnetic declination varies from place to place, and the probable position and epoch of the line of least diurnal variation near the equinoxes. For this object two stations were chosen—one near the magnetic equator, 90 miles north of Trevandrum, the other about 40 miles south at Cape Comorin, where continuous hourly observations were made during several months about the periods of the equinoxes. The most marked of the conclusions arrived at from these observations were, that the minimum diurnal variation near the March equinox occurred earlier in the year at Trevandrum than at Shertally 90 miles north, and on the magnetic equator; that the law presented marked differences at the two places, near the epoch of minimum variation; and that the difference of the variations at the two stations occurred almost wholly between midnight, sunrise, and noon, the difference between noon, sunset, and midnight being comparatively small.

2nd. Projected observations were exhibited in proof of the results communicated by the author to the Leeds Meeting of the Association, that the daily mean intensity of the earth's magnetism increases as a whole or diminishes as a whole; so that if at any point on the earth's surface the daily mean intensity increases, it will be found that it increases similarly at all other places in proportion to the absolute intensity at each place, allowance being made in cases of great disturbance to the greater value of disturbances in high latitudes.

3rd. Projected observations were also exhibited, showing that the *mean daily* easterly declination of the north end of a magnet followed on the whole the same law of variation in both hemispheres, differing from the diurnal variation, where the north end moves east in the southern hemisphere, while it moves west in the northern hemisphere.

4th. The author had investigated the laws of the diurnal variation of the barometer within the tropics. He had endeavoured to determine whether the chain of the Indian Ghats had any influence on the great atmospheric semidiurnal wave moving westward. Hourly observations had been made for a month in 1857, at a station on the eastern base of the Ghats, on the highest peak in Travancore, on the western base (all within a few miles), and at Trevandrum 20 miles distant, near the sea shore. Similar observations had been made in 1858, at four stations on the western face of the Agastier Malley, differing by 1500 to 1700 feet from each other in height, in correspondence with the Trevandrum Observatory. In these observations the greatest care was taken to have the best instruments, the times of observations were precisely simultaneous, and instruments of all kinds were observed likely to give results related to the question examined: fifteen observers were employed, and the observations continued hourly during a month. From these observations, it appears that the semidiurnal law of atmospheric pressure is the same at all heights up to 6200 feet (on a sharp peak), from 9 P.M. to 9 A.M., both as regards epoch and range. The day variation (9 A.M. to 9 P.M.) is greatest for the lowest station, depending evidently on the temperature. The author connected these facts with the hypothesis proposed by Dr. Lamont and himself, that the semidiurnal variation is due to the inducing electrical action of the sun on our earth and its atmosphere.

These and several other results, at present only partly worked out, would be published soon in detail. The printing of the observations made in the observatory of His Highness the Rajah of Travancore was proceeding as rapidly at Trevandrum as could be expected in India, and the first sheets were in the author's hands.

On the Diurnal Variations of the Magnetic Declination at the Magnetic Equator, and the Decennial Period. By JOHN ALLAN BROUN, *F.R.S.*

Solar-diurnal Variation.—The author stated that the observations made at the intertropical observatories had shown the fact that the law of solar-diurnal variation was opposite, or nearly opposite, at two seasons of the year; this result was made generally known to the scientific world by General Sabine, in his discussion of the St. Helena Observations. St. Helena, however, is too far from the magnetic equator to show the change from one law to the other, otherwise than as a shifting movement of the maxima and minima, which seem to slide in the course of a month or two from one position to the other; the whole range of the variation being considerable at all seasons. Mr. Broun offered to the Section the results of five years' observations made at the Trevandrum Observatory, about 90 miles south of the magnetic equator, which showed perfectly the mode of variation of the diurnal law.

In the months of December, January, and February, the *minimum* of easterly declination occurs at 7½ A.M., in the months from April to September, the *maximum* occurs at exactly the same time. In the months of March and October a period of indifference is attained, when the variation becomes nearly zero, or the variation is a series of maxima and minima at different hours, and the range or total angular movement is reduced to about thirty seconds (0'·5) when the mean of a few days is taken. The epochs at which this change takes place are neither those of the sun's crossing the equator nor the zenith, and the epoch seems to vary from year to year. The March epoch is not distant from the vernal equinox, but the other occurs nearly a month later than the autumnal equinox. So far is the second epoch for the change from one law to the other from that of the sun's crossing the zenith or equator, that August and September are the months of greatest diurnal range.

Although Trevandrum is in 8½° north latitude, it has a magnetic dip of 2½° south; but the diurnal variations affect the character of the northern hemisphere more than that of the southern hemisphere,—the mean range for the months from May to September being nearly three minutes (3'), while for the months of December and January the range is only about two minutes (2').

Mr. Broun was the first to point out that the diurnal law at any place might be represented by the superposition of two variations, one resembling that peculiar to high north latitudes, the other resembling that peculiar to high south,—the northern part being always in excess in high magnetic north latitudes, and in excess for places in low magnetic north latitudes only for the sun north of a given line. It is evident that we may, by descending towards the magnetic equator, reach a station where for a given position of the sun the two variations will be equal or nearly equal, in which case for that position of the sun the complete extinction of the diurnal law may be expected; this occurs approximately at Trevandrum.

When the diurnal range is examined with reference to the decennial period, it is found that the mean range had a minimum in the year 1856, the exact epoch of minimum being, perhaps, about January of that year; but when the ranges for given months are considered, some curious differences from the law are discovered. The yearly mean of monthly mean ranges, with the mean ranges for the months of March and October, are as follows:—

	Yearly Mean. ′	March. ′	October. ′
1854	2·244	0·569	1·336
1855	2·045	0·623	1·050
1856	2·009	0·849	1·075
1857	2·150	0·948	0·989
1858	2·414	1·265	1·091

It will be perceived from this Table that the range for the month of March has gone on increasing from 1854 till 1858, the range for the latter year being more than double that for the former; that while the minimum for the whole year occurred in 1856, that for March occurred in 1854, or before that year. In the case of the month of October, the ranges differ little, that for 1854 being the greatest, and that for 1857 the least. It is conceived by the author that this curious variation in March and October is connected with a shift in the epoch of minimum diurnal variation. If this epoch happen near the middle of the month, the range for the mean of the month will be least; if it happen earlier or later, the greater range of the preceding or succeeding periods will preponderate in the monthly mean. Should this be the cause of the variation of range for March and October, it would follow that the two superposed variations which produce the total variation may change their relative values from year to year for a given place and for a given position of the sun.

Lunar-diurnal Variation.—This variation, which was first remarked by M. Kreil, and afterwards, though quite independently, by the author, has since been discussed by General Sabine. The latter gentleman has made it a subject of inquiry, first, whether the lunar-diurnal variation within the tropics obeyed different laws for the moon north and south of the equator, like the solar-diurnal law; and 2nd, whether the decennial period could be perceived in the former as it is in the latter. His conclusions in both cases have been in the negative. Mr. Broun has discussed five years' observations at Trevandrum, from which he arrives at the following results.

1st. That the lunar-diurnal law varies with the moon's declination, but not to the extent of inverting the law. In all cases there are two maxima of easterly declination near the superior and inferior transits, and two minima for the moon near the horizon. If we consider the period about the solstice of December, we shall find that the greatest maximum occurs at the inferior transit for the moon furthest north, and at the superior transit for the moon furthest south. The greatest minimum is near moonrise for the moon on the equator going north, and near moonset for the moon on the equator going south, while the minima are equal for the moon furthest north and furthest south. The epochs also vary slightly.

2nd. The lunar-diurnal law, which remains nearly constant as regards epochs for all positions of the moon at any given season of the year, is the inverse in June of what it is in December; so that, for the sun furthest north, the lunar-diurnal law has its maximum where for the sun furthest south it has its minima, the latter occurring near the epochs of transit in June and July. In this way the ***lunar-diurnal law depends on the position of the sun*** relatively to the ecliptic, and not (or little) on that of the moon.

The range of the lunar-diurnal variation is greatest near perihelion, which is just the reverse of the solar-diurnal law; this appears to depend on the moon's greater proximity to the sun as the cause of its magnetic action. The range is least near the epochs of the equinoxes, as for the solar-diurnal law.

The cause of the great differences found by General Sabine in the laws for different places in the same hemisphere, is attributed by the author partly to the combination of laws which vary considerably at the same place for different seasons. The author also pointed out that General Sabine's failure to discover the decennial period in the lunar-diurnal variation may be due to the fact that, before he commenced his discussion, he had first cut out all the disturbances beyond a certain limit, so that a greater proportion were rejected in the years of greatest disturbance. The decennial law is one affecting the regular diurnal variations, chiefly, through the disturbance; so that if the latter be omitted the effect should not appear (or appear but slightly) in the former. The projected observations were exhibited to the Section.

On a New Induction Dip-Circle. *By* JOHN ALLAN BROUN, *F.R.S.*

The idea of determining the earth's magnetic intensity by its inducing action on soft iron was employed by Dr. Lloyd for the purpose of obtaining the magnetic inclination. A soft iron bar being placed vertically, so that the induced magnetism of one end should act on a freely suspended magnet, the deflection thus produced was observed, and considered proportional to the vertical component of the earth's magnetic intensity; the bar was then placed horizontal, and, the same end acting, the deflection was observed, which was in the same way considered proportional to the horizontal component: were there no sources of error, the inclination might be determined from these two angles. The iron bars employed always possess or acquire a certain amount of induced magnetism, the effect of which is eliminated by inverting the bar for the different deflections; there are, however, still two sources of error which remain. The most important is that due to the different actions of the different parts of the bar in the vertical and horizontal positions. If the whole magnetism were accumulated in one point at the acting end of the bar, this source of error would not have existed; but as the magnetism is distributed over the whole length, that part whose action is equal on both ends of the suspended magnet when the bar is in the vertical position, becomes greater on one end of the magnet than the other when the bar is in the horizontal position. It was probably for this reason that Dr. Lloyd's method has never been put into practice.

Last year, while observing with Dr. Lamont's theodolite magnetometer, Mr. Broun employed a method for the determination of the absolute magnetic inclination, to which it is believed there can be no objection in low magnetic latitudes, and which, with the modifications proposed, may probably be used in all latitudes.

In Dr. Lamont's apparatus the variations of magnetic dip from place to place are determined by means of two soft iron bars clamped to a horizontal ring, the ring surrounding a freely suspended magnet, one bar vertically above the ring, the other vertically below it. By a series of observations of the deflections produced by the bars in different positions, inverted and exchanged from side to side, the effect of permanent magnetism is eliminated, and the deflection due to the earth's force is obtained; the sine of this angle, multiplied by a constant, gives the dip for each place; the constant, however, requires the aid of the usual dip apparatus for its determination. It is evident, however, that if we can incline the bars moving in the plane of the magnetic meridian till the observed deflection be zero (should there be no permanent magnetism), and observe the angle through which the bars have been moved from the vertical, this angle will evidently be that of the magnetic inclination, for the bar will have been moved into the direction at right angles to that of the total force. This method, as thus stated, requires the determination of the vertical position of the bars; and it is supposed that there is no permanent magnetism: as far as the latter supposition is concerned, the error is eliminated by reversing the bars; in order to render the determination of the vertical position unnecessary, it is only required to observe the angular inclination of the bars, which (for each position) diminishes the deflection by an amount equal to the mean deflection previously obtained. It will be observed that for low latitudes, where the bars are moved little from the vertical, the objection applying to Dr. Lloyd's method exists to so small a degree as to be negligible.

This method, which Mr. Broun employed in India, is, however, liable to error in high magnetic latitudes; and the following is proposed for use in all positions. A small magnet, 2 inches long, is suspended by a silk fibre as with the usual declination magnet; a small mirror attached to the magnet allows the determination of the magnetic meridian by means of a telescope having a prism near the wire at the eyepiece, as in Dr. Lamont's apparatus. When the wire coincides with its image reflected by the mirror (no disturbing cause being near), the magnet is in the magnetic meridian. A vertical circle in the magnetic meridian parallel to the magnet, and 3 inches distant, centre to centre, has a soft iron bar clamped to the alidade, so that the acting pole of the bar is opposite the centre of the circle and the middle of the magnet. The reading of the circle is first obtained for the bar vertical: the verticality of the axis of the bar may be determined in different manners; the best, perhaps, is to have the bar hollow, and to employ reflexion of a cross wire from a surface of mercury. The bar is then moved in the magnetic meridian from the vertical position till the deflection of the magnet is zero; if the permanent magnetism acts with the induced magnetism, the movement of the bar will be greater than the inclination by a given angle; in turning the bar in the opposite direction (so as to invert it), the angle from the vertical will be less by the same amount.

Since in the position at right angles to the magnetic force the induced magnetism is zero, the objection applying to Dr. Lloyd's method does not exist; there is, however, still a source of error remaining that applies to both: as the magnetic inclination increases, the position at right angles to the force can only be attained by moving the bar nearer and nearer to the horizontal, and as it approaches the horizontal, a certain amount of magnetism is induced in the bar by the small suspended magnet. Different methods have been imagined by the author to destroy or balance this action; but the best method he thinks will be to make observations with the bar at two different distances. The magnetism induced by the small magnet in the bar may be represented by a weak magnet, whose force will vary inversely as the cube of the distance: as the action of this weak magnet will also vary inversely as the cube of the distance, the effect may be determined and eliminated by observations at two or more distances.

Any error of the observation for the vertical position of the bar due to the non-coincidence of the axis of magnetism and of figure may be eliminated by turning the bar on its vertical axis of figure through 180°.

The author remarked that the error due to the inducing action of the small suspended magnet might be rendered as small as we please, by employing a modification of the method used by him in India. If the total deflection due to the bar vertical (direct and inverted) be determined, and we then observe the change of deflection due to a given angular movement of the bar from the vertical, we may *compute* the movement necessary to render the deflection zero: the angular movement may be taken of such magnitude as to render the effect of the inducing action negligible. This modification requires, however, the determination of the angles of deflection, and therefore is far from the simplicity of the first method. The author pointed out, that, since when the bar is at right angles to the direction of the total force any small movement of the bar will produce induced magnetism in proportion to the *sine* of the small angle of movement, this position is that best fitted to give the true position of the magnetic meridian with the least error of inclination.

The author concluded by stating that he had learned since his return to Europe that Dr. Lamont had also proposed a method differing from that of Dr. Lloyd. Dr. Lamont employed an astatic needle, and turned the bars into different azimuths by movement on a vertical axis, so as to produce different amounts of induced magnetism without changing the position of the bars relatively to the vertical. This method, Dr. Lamont informed the author, had failed on account of the bars receiving different amounts of permanent magnetism in changing from azimuth to azimuth. This difficulty does not exist in Mr. Broun's method, as the bar is always kept in the meridian, and is always brought to the position where the inducing action is zero.

On Magnetic Rocks in South India. *By* JOHN ALLAN BROUN, *F.R.S.*

The Moocoonoomalley is a granite hill rising about 800 feet above the sea, 5 miles south-east of Trevandrum, and about 35 miles north-west of Cape Comorin. General Cullen, the late British Minister at Travancore, had observed several anomalies in the magnetic dip in ascending this hill. The dip near Trevandrum and about the base of the hill was from 2° 30′ to 2° 40′ S.; on the top he found the dip to be from 5° 52′ to 11° 23′ in different years, in which he probably slightly varied the position of observation.

In December 1855 I examined the rock masses constituting the hill. The plain around the base is formed of a stratified rock known to Indian geologists by the name of laterite. The first rocks in the ascent are dark syenites, containing a considerable proportion of hornblende (in some cases the appearance is more like a greenstone); towards the middle of the ascent light-grey syenites become common, and at the top the rocks are pegmatites or granites. I first examined a small fragment of the rock presented to me by General Cullen, of a greyish-red tint, composed chiefly of felspar and quartz with particles of magnetic iron ore disseminated; these particles were of about $\frac{1}{16}$ to $\frac{1}{30}$ inch in diameter, and without any regular form or smooth face (as far as my examination went), when a magnet was presented to one of these particles, detached from the specimen, it showed its polarity by tumbling over, if the homonymous pole was at first nearest the magnet. The specimen alluded to was about 5 inches long, 2⅓ inches broad, and 1⅓ inch thick, tapering and thinning off to one end (A). On presenting the different extremities to a freely suspended magnet (the declination magnet of the Trevandrum Observatory), the following results were obtained:—

	Sc. div.
Specimen away. Declination reading	0·00
End A presented	−1·64
„ B „	+2·13
Side C „	−1·17
„ D „	+0·73

where the negative sign signifies repulsion of the north end of the magnet, and the positive sign attraction of the same pole. The changes of magnetic declination occurring during the experiments were observed by another instrument, and have been subducted. As the line of the magnetic axis of the specimen was evidently towards the direction of its greatest length, the northern end being towards A and C, it was desired to determine whether the same relation would hold true for any fragment; for this purpose, two ends of the specimen were knocked off, leaving a fragment in the middle with a distance of *a* (towards A) to *b* (towards B) of nearly 2 inches, while the breadth from C to D was nearly 3 inches; so that the longest dimension was now nearly at right angles to that of the whole specimen. The central fragment being placed at the same distance from the suspended magnet as in the previous experiment, the following were the results:—

	Sc. div.
Fragment away. Declination reading	0·00
End *a* presented	−0·79
„ *b* „	+1·31
Side C „	−0·57
„ D „	+1·11

The ends and sides show the same polarities as in the whole specimen, but with the north end of the magnetic axis turned more to the side D, for which the deflection has increased. Upon presenting the small fragment constituting the end A of the specimen, the results were as follows:—

	Sc. div.
Fragment away. Declination reading	0·00
End A presented	−0·36
„ *a′* „	+0·36
Side C „	+0·14 ?
„ D „	+0·14

Here it will be observed that the broken fragments of the specimen acted exactly as the broken parts of a magnet; thus the end *a* in the central fragment gave a repulsive effect of 0·79 scale divisions, while the end *a′*, the opposite face of the fracture, gave an attractive action of 0·36.

Several questions of interest presented themselves in connexion with these rocks. Whether the hill as a whole would give results similar to those obtained from this specimen? Whether the lines of magnetic force in it had any relation to the lines of crystallization, or to those of the earth's poles? Whether any particular direction was most favoured? or whether the magnetic axes vary from spot to spot, and the magneticules, possessing their present magnetism when tossed up in the liquid mass, had their positions determined by chance?

On the 11th of December, 1855, I visited the hill, making observations with a 6-inch dip-circle by Robinson; the following differential results were obtained without reversing the poles of needle:—

		°	′
10th December, 1855, 6h A.M.	Base of hill	2	0
8h to 10 A.M.	Top of hill. Circle 4½ feet above rock A	3	34
	„ Circle ½ foot „	1	6
	„ Circle 4½ feet „ B	1	30
	„ Circle ½ foot „	14	5
Noon.	Base of hill over laterite	1	50
4h P.M.	Trevandrum Observatory	1	55

The bearing of the Trevandrum Observatory was observed approximately by a hand compass at the stations A and B. At 4½ feet above the rock the error was small; but when placed on the rock A, the declination was found 10° west, while on B (9 feet W.N.W. of A) it was 35° east, the true declination over laterite being about ½° east.

The pegmatite and granite on the top of the hill seemed to form kinds of dykes running parallel to each other nearly north and south, and crossed by lines nearly at right angles to the direction, so as to form large blocks, between which the decaying rock has allowed the accumulation of soil to some depth. Blocks of about 9 inches diameter were cut out of the rock at A and B, having previously marked the direction of the true north and south upon the upper surface, which was nearly horizontal. With these specimens I made the following observations. A specimen was placed with its centre at about 2 feet from the centre of the freely suspended magnet, and in the line at right angles to the direction of the magnet; the points of the compass marked on the upper surface, when the specimen was *in situ*, were successively presented to the centre of the magnet, and the scale readings of the instrument were observed. The direction of the *plane* of greatest force being found, the specimen was inclined at different angles to the horizontal, till the direction of the *line* of greatest force was determined.

Specimen A: elliptic cylinder, axes 9½ inches and 8 inches, average height about 5 inches; a granite containing a small quantity of hornblende, colour reddish grey; from about 1 foot west of the position A for the dip observation. The numbers following are in scale divisions, each equal 15″ nearly:—

N. deflection	+21·4	S. deflection	−17·8
N.N.E. „	+19·1	S.S.W. „	−17·3
N.E. „	+15·3	S.W. „	−15·3
E. „	+ 0·8	W. „	− 2·3
S.E. „	−12·3	N.W. „	+14·5
S.S.E. „	−15·4	N.N.W. „	+19·9
S. „	−17·8	N. „	+21·4

The direction of the plane containing the magnetic axis is in this case nearly north and south. On raising the point S. presented to the magnet, it was found that the north end of the magnetic axis dipped from 10° to 20° below the south horizon; the exact position could not be determined, from the difficulty of keeping the centre of the specimen always at the same distance from the magnet. The result agrees with the fact that the dip observed on A was diminished, since the rock magnet having here its south end uppermost, would necessarily attract the north end of the dipping needle.

Specimen B: cylinder 10 inches diameter, 9 inches deep; upper surface red and weathered, interior bluish grey; contains besides the bluish felspar and quartz a large quantity of hornblende. The observations for B were made only for the north end of the axis.

N.N.W. deflection	−36·4
N. „	−38·8
N. by E. „	−44·0
N.N.E. „	−42·4
N.E. „	−36·0

The north end of the magnetic axis was here evidently nearly in the direction N. by E. ½ E. Upon raising this point of the stone, presented to the centre of the magnet, the deflection diminished; on lowering it, the deflection increased to 10°; so that the north end of the axis here inclined 10° above the horizon to N. by E. ½ E. This result also agrees with the increase of dip found at B.

In a third specimen examined, which was weakly magnetic, the north end of the axis made an angle of 80° above the N.W. by W. point of the horizon.

From these results it is evident that though the direction of the magnetic axis may not vary much in small specimens, it does so in parts of the rock separated by a few feet only from each other; and it appears probable that it may be considerable for smaller distances than those under experiment. Neither do the directions of the axis seem to have any relation to the lines of crystallization.

Another question was examined by me, namely, whether the magnetic intensity of the rock varied with the temperature. For this question I chose a specimen of about 6 inches long by 4 broad and 3 thick, taken from near the middle of the ascent of the hill. The observations were made in the same manner as for the temperature coefficient of a magnet. The specimen was placed in a wooden trough, into which water of different temperatures was poured: the deflections of the declination magnet by the specimen at different temperatures were noted; the variations of declination during the experiments were eliminated by means of another instrument. The results are contained in the following Table:—

Trevandrum Mean Time.			Temperature of stone, Fahr.	Scale reading corrected for declination.	Change of Temperature.	Change of Scale reading.
	h	m		Sc. div.		
Dec. 20.	19	30	Stone away	81·67		
		53	67°	139·77	+88°	−1·07
	20	13	155	138·70	−80	+1·00
		37	75	139·70		
		52	Stone away	81·82		

The result is that the magnetic rock, like a steel magnet, loses force by an increase of temperature; and, using the notation employed for steel magnets, the temperature coefficient is approximately

$$q=0·000214,$$

nearly the value obtained for steel magnets used in the British and Colonial Observatories.

The following may be considered as the conclusions at which I have arrived:—

1st. The rock fragments have determinate magnetic axes.

2nd. Broken fragments resemble broken magnets, showing opposite polarities at the two surfaces of fracture.

3rd. The magnetic axis varies from place to place within small distances.

4th. The action of the whole hill on magnets freely suspended at moderate distances is nearly imperceptible; the opposite directions of the magnetic axis in the rocks rendering the total action nearly zero.

5th. As in some cases the north end of the magnetic axis was found to the southward (as with specimen B), we cannot suppose that the magnetism of the small magnets has been due to the inducing action of the earth in their present position or since the rock mass became solid.

6th. The directions of the magnetic axis have no relation to the lines of division of the rock masses.

7th. The magnetic force of the rock masses varies with temperature like that of steel magnets.

On a Magnetic Survey of the West Coast of India.

By JOHN ALLAN BROUN, *F.R.S.*

This survey was undertaken at the expense of His Highness the Rajah of Travancore, for the purpose, in the first instance, of determining the exact position of the magnetic equator (which passes through his territory) and the variations of intensity about the line of no inclination. This part of the survey was performed with considerable care, stations being chosen along the line of coast, at distances of from 10 to 15 miles, generally far from the chain of the Ghats, and in a flat country, covered in many places by backwaters or lagoons. The instrument employed was the excellent theodolite magnetometer of Dr. Lamont. The results were, that the magnetic south inclination, instead of diminishing regularly from Cape Comorin northwards to the line of no dip, diminished through a space of 30 miles, increased through a similar space, and again diminished in the most capricious manner. The same irregularities were observed north of the estimated position of the equator. Some irregularities had been already observed by Mr. Caldecott, Mr. Taylor, and General Cullen; but the author had confirmed his results by observations at many different stations, and had come to the conclusion that a belt of disturbance for this element existed near the line of no dip. This disturbance could not be attributed to the influence of hills or of rocks, as no ground of greater elevation than 30 to 40 feet existed within several miles of those stations showing the greatest irregularities, no rocks were reached by borings of 30 to 50 feet deep, and none appeared upon the surface above the sandy soil near these stations.

The survey was extended by the author on his way to Europe by observations at stations further north than those in Travancore, as Kodungalur, Kalikut, Mangalur, Goa, Rutnagherri, Bombay, and Aden. From this and the first part of the survey, the author found that the horizontal intensity was nearly the same from Cape Comorin to Bombay, showing, as the author conceived, that the lines of equal intensity followed (somewhat like the isothermal lines) the line of the Indian coast. This result agrees with that obtained by the Messrs. von Schlagintweit, whose previous observations indicate a great bend of the isodynamic lines from the Himalayas and towards Cape Comorin. The whole question, the author conceived, required careful examination by means of observations at more numerous stations, as the theory of the causes of the earth's magnetic intensity, and the arrangement of the magnetic lines, were evidently involved in results which differed so much from what had been found elsewhere, especially from the results obtained by Dr. Lamont from his admirable magnetic survey of the greater part of the European Continent.

On the Velocity of Earthquake Shocks in the Laterite of India.
By JOHN ALLAN BROUN, *F.R.S.* (See GEOLOGY.)

On a Mode of correcting the Errors of the Compass in Iron Ships.
By A. CLARKE, *New South Wales.*

On Electrical Force. *By* Sir W. SNOW HARRIS, *F.R.S.*

The author adverted to the assumed existence in nature of an electric fluid or fluids, an idea entertained by philosophers from the earliest periods of the history of electricity. Many thought that all bodies expire or inhale this fluid. In modern times less ambiguous views have been resorted to, and the doctrine of an electric fluid or fluids has been employed principally as aiding to link the phenomena into an intelligible and connected chain. The author thinks the time is fast approaching when it may be found desirable to abandon all idea of electrical fluids as the agency concerned in the development of electrical force, and treat this species of force as Newton did gravity, without any care as to its occult quality. For although it may be convenient and perhaps useful to employ analogical expressions in interpreting the phenomena and to facilitate description, as when we speak of the quantity of electric matter, of its tension, density, or thickness of stratum, &c., yet it must ever be remembered that, in using this figurative language, it is force and the laws of force with which we are dealing, and not with electrical fluids or other assumptions as to its occult nature or quality.

The author proceeded to say that the foundation of all exact science is number, weight, and measure; and that, as observed by an eminent writer, no branch of physical knowledge could be held as being out of its infancy which did not in some way or the other frame its theory, or correct its practice with reference to these elements. He here described and explained the nature of a series of very beautiful instruments, by which the quantity of the electrical agency, its attractive force, its explosive power, and the effects produced, could be accurately measured. Having thus endeavoured to bring the unknown agency we term electricity under the dominion of number, weight, and measure, the leading characteristics of electricity as a force were next brought under consideration. And first, we observe electrical power exhibits itself under two forms, usually termed vitreous and resinous electricity, or positive and negative electricity. These have been usually considered as arising out of two distinct and separate fluids, or of a single elementary fluid in a greater or less state of condensation. They are, however, one and the same force, and have the same relation to each other as the forces of compression and extension in the case of a bent bow or spring. We cannot have one without the other; and as in the latter instance we should gain but little by assuming the existence of elastic fluid or fluids as the source of elasticity, so in the case of electrical force we may as well look at once upon positive and negative electricity as elementary facts of which we have no adequate explanation.

Secondly, we observe that whatever be the nature of electricity as a physical agency, it cannot exert itself equally in all directions at the same moment. In the case of gravity, the sun does not attract the earth with less force because it is exerting its gravitating power on the other planets. Such is not the case in the development of electrical force. The author here introduced a striking experiment in illustration of this; showing that a delicate electroscope, attracted toward an electrified circular plate placed vertically, became less forcibly drawn toward the plate from a distance when a second body was brought to share in the action. This is the result of a third characteristic of electrical force, termed electrical induction or influence, the laws and operation of which were now further explained and illustrated. It is solely upon this species of electrical action, apparently of a sympathetic kind, operating at a distance, probably by propagation through the intervening medium, that electrical attractive force altogether depends: without it no exertion of power is possible. In electrical force bodies are first rendered attractable before they become attracted, and for the regular and full exertion of the attraction, both the bodies must be susceptible of unlimited electrical change. When this is the case the development of force is easily traced; and the force will be found to vary as the square of the quantity of electricity in operation directly, and as the squares of the distances inversely: of this some striking and very interesting experimental illustrations were given through the instrumentality of the electrical balance, delicately set up with complete means of adjustment for distance and force; and it was with remarkable precision the beam descended when under the influence of two attracting surfaces; the quantity of electricity and the weights being given, the force of induction, upon which the resulting force depends, varies in the simple inverse ratio of the distance between the attracting surfaces, and depends, first, upon the direct influence of the electrified surfaces, secondly, upon a reflected induction thrown back upon the excited body. The total force is in a compound ratio of these forces, and it is in this way we obtain a force in the inverse duplicate ratio of the distances. If from any cause either or both of the previous elementary actions be interfered with, then we have no longer this law; so that any law of electrical force is possible, as found in the experiments of many eminent philosophers of past days—Muschenbroek, Brook, Taylor, Whiston, Martin, and others. The author thinks that the results of the experiments of these eminent men have been called unjustly in question; every result they arrived at is producible by careful manipulation.

The author now brought under consideration the question of electrical force between spheres, one charged with electricity, the other neutral and in a free state. This question had been often elaborately treated, and had been hitherto considered a physico-mathematical question of great intricacy. An analysis of the elements of this question was here entered upon. Upon the proved facts that the force varies with the quantity of electricity and is in the duplicate inverse ratio of the distance, two points may be found within the opposed hemispheres in which we may conceive the whole force to be collected, and to be the same as if proceeding from every point of the opposed hemispheres. These points approach the surface, and become the touching points when the spheres touch; as the spheres separate they approach the centre, and reach the centre when the distance is infinite. If we call a the distance between the points of contact, and r=the radius of sphere, we have, putting F=the total attractive force, $F \propto \frac{1}{a(a+2r)}$; and calling the points of centre of force=$q\,q'$, we have distance $q\,q'$=the tangent from either of the touching points to the opposite sphere; or if distance $q\,q'=D$, we have $F \propto \frac{1}{D^2}$, or $\propto \frac{1}{T^2}$.

Several very remarkable experiments were now adduced in evidence of the truth of these formulæ. Spheres of variable diameters were put in opposition in the balance, the quantity of electricity measured, and weights placed in the scale-pan, as determined by calculation; the distances being regulated accordingly, the scale beam bowed in obedience to the given law of force with extreme and wonderful exactitude: the experiments elicited much commendation.

The author thinks that every observed operation of electrical action is reducible to simple and elementary laws free of complication, and may be investigated and expressed by an easy mathematical analysis and forms of expression. He thinks that all the laws of nature are of the most simple kind, and only involve a simple relation of cause and effect; if we double the cause we double the effect. To suppose an effect to be as the square or cube of its cause, is to suppose the effect to depend partly on the cause and partly on nothing. There is probably, taken as a simple elementary law, no such a law in nature as that of a force being in the inverse duplicate ratio of the distance. Take, for example, the case of gravity as central force, and assumed to be a species of emanation from a centre, it is true that at twice the distance we have only one-fourth the force; but this is because the areas of the concave spherical surfaces, which we may imagine the emanation to fall upon at these distances, are to each other as 1 : 4; so that in any one point of the outer sphere there is only one-fourth the agency upon which the force depends, consequently only one-fourth the attraction: but this is a simple relation of cause and effect. Taking light as an emanation from a centre, the same result ensues. If there be only one-fourth the quantity of the emanation in any point, we can only have one-fourth the light, and thus light or gravity may be said to be in the inverse duplicate ratio of the distance.

On the different Motions of Electric Fluid. By the Rev. T. RANKIN.

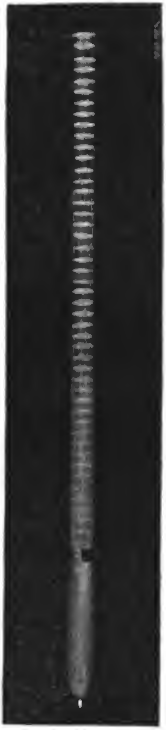
The author, from several very striking and vividly-described thunder-storms and their permanent effects, concludes that sometimes the electric fluid moves downward, sometimes upward, and sometimes horizontally. On one occasion, some years since, about two o'clock, on a night on which it had thundered almost incessantly, a loud whizzing sound was heard to pass over the rectory-house, which he judged to be an aërolite; a tree in the direction it had passed was struck; and from the nature of the injury inflicted, the conclusion was drawn that the motion of either the aërolite or of the electric fluid had been nearly horizontal.

On the Phenomena of Electrical Vacuum Tubes, in a letter to Mr. Gassiot. *By* Professor W. B. ROGERS, *Boston, U.S.*

I send you, by my brother, a printed abstract of remarks made some months ago on the phenomena of the vacuum tubes, and a hypothesis as to the condition and cause of the stratifications.

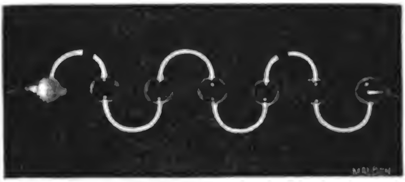
You will see that, with the aid of Mr. Ritchie and our skilful photographer, Mr. Black, I have been experimenting on the actinism of these electrical discharges.

In some more recent trials I have obtained beautiful photographs of the stratification, of which I send you a specimen. The tube, as you will see, is a straight one, of uniform calibre. It is about 15 inches long, by $\frac{3}{4}$ inch diameter, and is marked by Geissler as containing phos. hydrogen. As you have perhaps observed, it gives the strata with extraordinary distinctness; and after the action has been continued a little while, the strata near the blank end *arrange themselves in pairs, consisting each of a bluish and a more reddish layer,* separated by a blank interval from the next, as seen very plainly in the photograph.

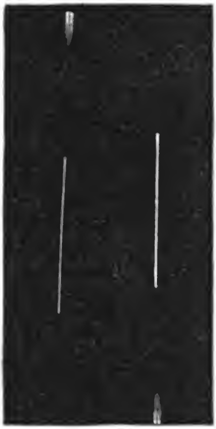


By a steady, rapid motion of the ratchet-wheel of Mr. Ritchie's coil, it was easy to keep the strata almost perfectly stationary. The picture was obtained with eighteen turns of the wheel, each giving twelve sparks. With six turns a tolerably clear picture was secured.

You see that the unilluminated space at one end made no impression, and that the intervals between the strata are also as devoid of actinic as they are of luminous rays.



The picture of the *winding tube*, with bulbs, shows how *superior* is the actinism of the faint *blue* light of the negative end compared with the brighter and less refrangible rays of the opposite bulb.



The third photograph was produced by the two slender Geissler tubes, containing respectively N and CO_2. The former was placed below the latter as they were presented before the camera, and the current was sent through them in succession. To the eye the intense whitest light of the CO_2 tube was more dazzling than the crimson colouring of the other. Yet you will observe the picture made by the latter is far the stronger of the two, as indeed might have been expected from its more refrangible illumination.

This photograph was produced with half a turn of the wheel, that is, six successive flashes of the light. I am unable to state the aggregate time of exposure to the rays, as I have not yet ascertained the duration of a flash. This I hope, with Mr. Ritchie's aid, to accomplish at an early day. But if we assume the time to be as much as tenfold the duration of the electric spark, as measured by Wheatstone, we should have less than $\frac{1}{20,000}$th of a second for the entire time which the light required for producing this intensely clear picture. I believe that a single flash would suffice, but I have not yet made the trial.

General Abstract of the Results of Messrs. de Schlagintweit's *Magnetic Survey of India, with three Charts.* *By* M. H. VON SCHLAGINTWEIT.

M. Hermann de Schlagintweit gave a general report on the results obtained during MM. de Schlagintweit's magnetic survey of India and High Asia, from 1854 to 1857.

He presented three charts, showing the lines of equal declination, dip, and intensity, from Ceylon up to Turkistán. Also the details of their observations as contained in the first volume of their work, 'Results of a Scientific Mission to India and High Asia,' undertaken by order of the Hon. East India Company, was laid upon the table.

The magnetic results were preceded by a communication of those latitudes and longitudes, particularly to the north of the Himalayas, which were either new as to localities or found to differ from previous determinations.

For the construction of their charts, they most carefully compared also the previous observations; such as, for the intensity in Northern India, Taylor's and Caldecott's, and particularly those recently made by Mr. Broun; for the declination along the coasts, the determination of the Indian Navy; but Capt. Elliot, their predecessor, having died before he could extend his survey from the Indian Archipelago to India, and the only detailed observations in the outer Himalaya (General Boileau's, at Simla) being destroyed in the last mutiny, their observations must be considered as made in a territory novel for this branch of science; and a great part of them was besides made under circumstances so difficult, that unhappily one of the three brothers was killed in Turkistán.

The following results are particularly to be mentioned:—

I. *Declination.*—1. A zone of too little easterly declination, of considerable extent, was found in Assam. 2. In the north-western part of India the declination was found to vary more rapidly than in the surrounding territories. 3. In the region of the Kuerluen the declination was found more easterly than given by the approximate form of the isogonic lines as provisionally laid down till now for these regions.

II. *The Dip.*—This was found, of the three elements, the most regular in its general forms; though local deviations are not unfrequent, they are small and very limited.

III. *Total Intensity.*—Two unexpected results presented themselves:—1. A decided inflection of the isodynamic lines in the central and southern parts of India. 2. A zone of depression all along the outer ranges and the base of the Himalaya.

In reference to the first, M. de Schlagintweit pointed out, as particularly important, that the very careful observations of Mr. Broun all along the western coast of India, made quite independent of, and subsequent to, their own, perfectly coincided with the lines based on their observations.

The magnetic influence of a large surface of soil exposed to the physical action of a tropical insulation, and the non-existence of such an influence in the rainy and much more clouded regions of the outer Himalayas, were named as perhaps not unconnected with this phenomenon, so particularly characteristic in India.

Outline of the Principles and Practice involved in dealing with the Electrical Conditions of Submarine Electric Telegraphs. *By* M. WERNER *and* C. W. SIEMENS.

The authors, who have had very extensive experience in dealing with submarine and other electric telegraphs, state that the failures of the more extensive submarine lines commence generally by a gradual decrease of insulation. The cause of this failure has been found, in repairing these lines, to consist in a disintegration of the gutta percha by the electrolytical action of the currents employed in working the line in such places where the insulating covering was much below the average thickness, owing to excentricities, cavities, &c. In other places, where the gutta percha had been of uniform and sufficient thickness, not the slightest destruction took place; but it might be laid down as an axiom, that *"so long as there are any thin places* *allowed to remain in the gutta percha coverings of a submarine conductor, so long will their insulation fail by slow degrees."*

Great improvements have of late been effected, which may be estimated by the fact that the covering of the Rangoon and Singapore cable, now in process of manufacture, insulates ten times better if reduced to the same thickness of coating than the covering of the Red Sea and India cable did before it was laid; and these marked improvements are due to the greater care used by the Gutta Percha Company, assisted by stringent electrical tests which the authors are charged by the British Government to apply.

The chief characteristic of these tests is, that the conductivity of both the conducting wires and the surrounding coating, which is regarded in the light of an inferior conductor, is expressed in numerical units, capable of direct comparison. The unit of resistance adopted is that of a column of mercury, 1 metre in length and of one square millimetre sectional area, taken at the freezing-point of water (as described by Werner Siemens in Poggendorff's 'Annalen,' vol. cx.). In expressing the degrees of conductivity of both the wire and the insulating medium in definite units of resistance, not only the advantage of a more accurate comparison between the results of different indication is obtained, but subsequently, when the separate coils are united together to a single cable, it affords an admirable means of judging its electrical condition in comparing the total resistances of both the conductor and insulating medium with the sum of the resistance previously obtained in testing each coil separately; but the principal advantage derived from this system of measuring, consists in the facilities it affords in determining the position of a fault in a cable while it is being laid and after submersion. In carrying this system into practice, MM. Siemens constructed coils of definite resistance variable from 1 to 50,000 units of resistance.

The cables to be tested are placed for twenty-four hours in water regulated to 75° F.; they are then removed into the testing tank of the same temperature, which is hermetically closed, and hydraulic pressure of at least 600 lbs. per square inch applied, in order to force the water into the cavities or fissures that may present themselves.

It is a remarkable fact, which is also borne out by observation upon cables in process of submersion, that the application of hydrostatic pressure sensibly decreases the conductivity of gutta percha; which, however, increases again slightly beyond the former rate when the pressure is relieved.

For a full description of the methods of testing employed, we must refer our readers to the paper itself.

The authors give a description of a new instrument by means of which they test the inductive capacity of cables, which has also to be accurately ascertained for the purpose of detecting faults; and have affixed a Table containing many satisfactory results, and proving the correctness of a formula for calculating the specific induction of cables, which was obtained by Professor Thomson and M. Werner Siemens by different scientific deductions.

The specific inductive capacity of all gutta percha is shown to be nearly the same, and to be entirely independent of the specific conductivity of the gutta percha; while India-rubber and Wray's mixture are far inferior in specific inductive capacity, being equal to 0·7 and 0·8 respectively, gutta percha being taken = 1.

In this way the cable is examined repeatedly at the earliest stages of its manufacture, in lengths of one knot, during the joining and covering of the cable, and finally during the paying out.

The paper next gives a full description of the electrical tests to be applied during the paying out, and numerous formulæ by means of which faults in the cable are ascertained under various circumstances. By these means Messrs. Siemens were enabled to determine with great accuracy faults in the Indian cable, both during the paying out and afterwards, which enabled the contractors, Messrs. Newall and Co., to effect the necessary repairs with a certainty which could not formerly be obtained.

Respecting the prospects of success of new lines of submarine cables, the paper states that, owing to the great care used, the conductor of the Rangoon and Singapore cable is fully ten times more perfectly insulated than the best cable hitherto submerged; and that it may confidently be expected that the result in practice will also greatly exceed that of previous experience; still the insulating material employed remains the same, and is therefore liable to be affected by the same causes of failure.

The frequent failure of gutta percha has given rise lately to several projects of substituting India-rubber and its compounds for the same, which, owing to the higher insulating properties and lesser inductive capacity of India-rubber, and above all, owing to its greater homogeneity and resisting power to effects of heat, give promise of valuable results in making electric telegraphs less liable to failure. The chief difficulty consisted hitherto in working India-rubber in such a way as to obtain uniform and perfect coatings upon the conductor without injury to the conductor itself. The authors have endeavoured to remove this difficulty in constructing a covering machine, which they brought before Section G of the Association.

They conclude,—"We do not wish, however, to rest upon our individual efforts for the further development of this important new branch of applied science. Our object in writing this communication has been to show that, although submarine electric telegraphs have often failed, the experience gained has not been lost; and that in bringing the present stock of knowledge to bear upon the subject more complete success may be ensured."

Astronomy.

On the Forms of certain Lunar Craters indicative of the Operation of a peculiar degrading Force. By W. R. Birt, *F.R.A.S.*

There are on the surface of our satellite three well-marked classes of lunar craters, those that are more or less complete in the outlines of the mountainous rings by which they are surrounded, having in many cases a somewhat *deep* interior, and appearing as excavations on the surface of the moon. Cleomedes, Geminus, and others in their neighbourhood are examples. We have also among the perfectly surrounded craters those that have their rings somewhat considerably elevated above the general level of the lunar surface. Tycho may be cited as the most perfect instance of the raised craters. Both these kinds agree in a very important particular; the surrounding ring (whatever may be the varying altitudes of different peaks, or however certain portions may rise higher than others) is in this class complete; there is no evidence of the operation of the peculiar degrading force, to which I shall presently allude—certainly not to any very great extent—in breaking down any portion of the surrounding annulus.

A second class of lunar crater consists of those that, having the surrounding ring complete, do not exhibit the depth of such craters above specified, or the gradual rising from the general surface as seen so distinctly in Tycho; they stand out as it were above those portions of the surfaces of the moon where they occur—generally the Maria—as if the smooth undulating plains had come quite up to the rings which rise abruptly from them. Most of these craters have smooth level interiors; and there are instances of the first class situated in rugged mountainous districts possessing also a smooth interior. Plato may be quoted as an example. Many instances of this class occur in which the ring is but slightly raised above the interior and exterior surfaces.

The third class, to which I am particularly desirous of referring, consists of such craters as having apparently at some previous period of their history possessed a perfect ring; a degrading force, not such as may have produced the terraces and ravines which we notice in Copernicus, but something of a different character, has invaded them from without, breaking down certain portions of the annulus, and leaving only a portion of the walls standing: these craters mostly occur on the borders of the Maria; and it is not a little significant that the broken portions are invariably, so far as my observations extend, on the side next the Maria, the parts of the annuli opposite the Maria being more or less in their earlier state.

The two undermentioned craters appear to be interesting examples of this class—Fracastorius, situated on the border of the Mare Nectaris, and Hippalus on the border of the Mare Humorum. The ring of Fracastorius is so much broken down towards the Mare Nectaris as to give the crater the appearance of a small bay, unless viewed under a suitable illumination—a very early one—when the edge of the crater towards the Mare is seen as a series of low points or peaks casting very short shadows. The floor of the interior appears to be somewhat different from the surface of the Mare, and seems to be slightly depressed below its level. The crater Hippalus is highly interesting; seen under a very early illumination: the western half of the floor is rugged, having a number of hillocks scattered over it and two minute craters; the eastern half is smooth, very like in appearance to the surfaces of the Maria; but the most remarkable feature is the line separating the crater from the Mare, just as though the Mare had come up to and swept away half the ring of the crater and a portion of its floor, the two extremities of the semicircular range of mountains being very distinct, especially the north-eastern, which terminates abruptly; not the vestige of a shadow is observed between the two, the light passing between them unobstructedly.

On the Possibility of Studying the Earth's Internal Structure from Phenomena observed at its Surface. By Professor HENNESSY, *F.R.S.*

This the author showed to follow as a result from the comparison of the level surface, usually called the earth's surface by astronomers and mathematicians, with the geological surface which would be presented if the earth were stripped of its fluid coating. He had made several comparisons of the arcs of meridian measured in different countries, and had been thus led to the conclusion that the surfaces in question were not only dissimilar, but that the former derived many of the irregularities which it is known to present from the influence of the obvious irregularities of the latter. In the absence of precise knowledge of the true figure of the surface of the solidified crust of the earth, as well as of the assumed level surface perpendicular to gravity, theory was necessarily somewhat in advance of observation upon this particular question. At present the number of unknown quantities involved in an inquiry as to the earth's internal structure was greater than the number of conditions; but by knowing the true surface, and adopting the results of established physical and hydrostatical laws relative to the supposed internal fluid mass*, we should be able to form as many equations as we have unknown quantities, and thus ultimately obtain a solution.

On some Recorded Observations of the Planet Venus in the Seventh Century before Christ. By the Rev. EDWARD HINCKS, *D.D., of Killyleagh, Ireland.*

There is a tablet of baked clay in the British Museum, the inscription on which, if I interpret it aright, contains a series of observations of the planet Venus, and a series of predictions grounded on the observations. The latter are of no value; but the former may in great measure, if not altogether, determine the law by which the Assyrio-Babylonian lunar year was regulated in respect to its intercalary months. The knowledge of this law, again, will either establish or disprove the view which I have long entertained, and repeatedly expressed, that the era of Nabonassar was an astronomical, and not a political one; and I may add, it is not impossible that it may furnish a test of the genuineness of the works attributed to Quthami and other supposed ancient Babylonian writers. For these reasons I am desirous that the observations which I suppose to be recorded should be submitted to astronomers. I now offer two, which will suffice to test the correctness of my interpretation of the records. If any astronomer will take the trouble to calculate whether what is here stated to have happened would have actually happened, and will communicate the result to me, I will, if he desire it, communicate to him other records of observations, as to the interpretation of which I feel less confidence than I do as to these. I observe that the Babylonian months are expressed by monograms, for which I substitute Hebrew names of months. The Babylonian day began at noon; and that day in the evening of which the new moon was first seen was considered to be the first day of the month. I suppose, but am not very confident, that the year of the first observation was −685. The month of Thamuz would begin in the spring. The second observation was some years later. "On the 25th of Thamuz, Venus ceased to appear in the west, was unseen for seven days, and on the 2nd of Ab was seen in the east." "On the 26th of Elul, Venus ceased to appear in the west, was unseen for eleven days, and on the 7th of the second Elul was seen in the east." This being an embolismatic year, the day last mentioned was necessarily its 184th day, and was 200 days before the first day of the new year. If, then, this day can be determined from what is recorded of Venus, the commencement of two Babylonian years out of a cycle of eight will be determined. The foregoing had been communicated to the Royal Astronomical Society, but is not yet published. Dr. Hincks now added his conviction, that by combining those observations with that of the equinox, recorded on another tablet, a translation of which was given by him in the Transactions of the Royal Irish Academy, the determination of the year in which any of those observations took place would determine the commencement of *every* Babylonian year. The Babylonians were acquainted with the approximate equality of eight tropical years, five synodic revolutions of Venus, and ninety-nine synodic revolutions of the moon. The first observation, if in the seventh century before Christ (which is probable, though not quite certain—later than this it could not be), must have been in a year of the form $-685 \pm 8\,i$.

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* See Reports for 1859, Trans. Sect. p. 5.

On the brilliant Eruption on the Sun's Surface, 1*st September* 1859.

By R. HODGSON, *F.R.A.S.*

While observing a group of solar spots on the 1st of September, I was suddenly surprised at the appearance of a very brilliant star of light, much brighter than the sun's surface, most dazzling to the protected eye, illuminating with its light the upper edges of the adjacent spots, not unlike in effect the edging of the clouds at sunset: the rays extended in all directions, and the centre might be compared to the dazzling brilliancy of the bright star α Lyræ, when seen in a large telescope with a low power. It lasted five minutes, and disappeared instantaneously about $11^h\ 25^m$ A.M. Telescope used an equatorial refractor, 6¼ inches aperture, carried by clockwork. Power single convex lens 100, with pale neutral tint sunglass. The *whole aperture* was used with a diagonal reflector. The phenomenon was of too short a duration to admit of a micrometrical drawing, but an eye-sketch was taken from which the enlarged diagram was made.

The only other observer was Mr. Carrington at the Red Hill Observatory, but a drawing was made of the spot by the Rev. William Howlett of Hurst Green, at noon, within half an hour of the occurrence. From a photograph taken at Kew the previous day, the size (length) of the entire group appears to have been about 2 minutes 8 seconds, or say 60,000 miles.

The magnetic instruments at Kew and Greenwich were simultaneously disturbed at the same instant to a considerable extent.

Prospectus of the Hartwell Variable Star Atlas, with six Specimen Proofs.

By JOHN LEE, *LL.D.*

The work announced is to form one of a series of quarto volumes, of which Admiral Smyth's well-known 'Ædes Hartwellianæ' and 'Speculum Hartwellianum' may be regarded as the commencement. It is to comprise maps of the vicinity of all stars of established variability,—at the present moment 102 in number. The light ratio or magnitude scale employed was explained, and six specimen proofs exhibited to the meeting. The scale of projection is unusually large and clear; 3 inches to one degree, to avoid crowding and confusion. After dwelling at some length upon the unsatisfactory state of our knowledge of the variable stars, and making allusion to the most recent researches and discoveries, especially to those of Professor Argelander, Sir John Herschel, Mr. Hind, and Mr. Pogson, and to the annual ephemeris of the variable stars published by the last named astronomer for four years past, Dr. Lee remarked,—

"A variable star usually remains unchanged for several nights, sometimes even for weeks, when either at maximum or minimum; and yet, owing to the difficulty of estimating absolute magnitudes correctly, and still more to the prevalence of haze and other uncertain atmospheric fluctuations, the most practised eye would fail to fix at all satisfactorily, either the time or amount of greatest or least brilliancy. By comparing the variable with neighbouring stars, which are of course similarly affected by atmospheric influences, most of this uncertainty is however avoided; and by careful consideration of the rapidity of increase and of decrease, the time of maximum or minimum is very closely and easily limited. In order to make such comparisons, it is requisite to know the absolute magnitudes of the stars of reference pretty correctly. A convenient number of stars in each map will therefore have the magnitudes annexed *in plain figures*, omitting the decimal points to prevent their being mistaken for faint stars; and it is to render this aid to future observers of variable stars that the 'Hartwell Atlas' is now being constructed."

On the Physical Constitution of Comets.
By Professor B. Pierce, *of Cambridge, United States.*

On the Dynamic Condition of Saturn's Rings.
By Professor B. Pierce, *of Cambridge, United States.*

On the Motion of a Pendulum in a Vertical Plane when the point of suspension moves uniformly on a circumference in the same Plane. By Professor B. Pierce, *of Cambridge, United States.*

METEOROLOGY.

On a Plan for Systematic Observations of Temperature in Mountain Countries. By John Ball, *M.R.I.A.*

Several members of the Alpine Club have agreed to unite in a plan of systematic observations of temperature in the Alps, and such other mountain countries as they may visit. It is possible that the plan of combined action may eventually be extended to other objects, but for the present it embraces only such observations as may be made with thermometers. As the intention of the present paper is merely to invite the suggestions, and if possible the cooperation, of members of the Physical Section, it seems unnecessary to state in detail the arrangements which are proposed; and it will be sufficient to indicate generally the points to which it is believed that the observations about to be commenced may most usefully be directed.

1st. The condition of the upper parts of high mountains in regard to temperature is most imperfectly known. It may not be possible to learn much by direct continued observations, but it is thought that by means of self-registering instruments we may add considerably to the little which is now known. It is proposed to place such instruments, and especially minimum thermometers, on as many of the higher peaks of the Alps as possible, and to register their indications in succeeding seasons. The chief practical difficulty in carrying out this branch of the proposed plan is to find positions at great heights that are free from winter snow. It will be necessary to select vertical or nearly vertical rocks in order to attach the instruments thereto, and these are not always to be found very near to the highest summits of great mountains.

2nd. It is a matter of much interest, but of considerable difficulty, to obtain measures of the effect of the lower strata of the atmosphere upon the radiant heat of the sun. The general opinion of mountain travellers is adverse to the use of the actinometer in any of the forms in which that instrument has yet been devised, and the same may be said in regard to other instruments proposed for the same purpose. The objections to observations with the black bulb thermometers are obvious and well known, but it is thought that observations made on a uniform plan, and with instruments of exactly the same dimensions and construction, would give comparative measures which would have some positive value. If it should be possible to obtain series of such observations made at two stations very different in elevation, and exactly simultaneous, they could scarcely fail to give valuable results.

3rd. We are very ignorant at present as to the mode in which disturbances of temperature are propagated from one place to another in mountain countries. Considerable variations of temperature are not unfrequent, and sometimes occur very rapidly, usually if not always in connexion with changes of wind; but we know very little of the way in which a disturbance of this kind is transmitted either in the horizontal or the vertical direction. It is conceived that a network of observations made by a considerable number of observers scattered over a district, such as Switzerland and Piedmont, would lead to some increase of our knowledge in this respect.

4th. Observations on the temperature of the surface and upper layers of the soil have a considerable bearing on many questions connected with the distribution of plants. One difficulty in investigating these questions arises from the difficulty of comparing observations not made upon a uniform plan. It is thought that the adoption of uniform instruments, and a plan of observations previously agreed upon by all the members of the party, will much increase the value of their results. All the instruments used in these observations are exactly of uniform construction, and made by Mr. Casella with the utmost practicable regard to lightness and convenience. Each instrument is numbered for purposes of future reference.

On Atmospheric Waves. By W. R. Birt, *F.R.A.S.*

The object of this communication is rather elucidatory than otherwise. It is now twelve years since I had the honour to lay before this Association the last of my reports on the subject. During the interval it has doubtless occupied the attention of other minds, and some degree of misconception may have arisen which may call for some elucidatory remarks on my part, especially as the series of reports in our annual volumes has been referred to on the Continent, as establishing a priority of investigation into these phenomena on the part of the British Association for the Advancement of Science.

It is now several years since Professor Dove announced as his conviction that the equilibrium of the atmosphere was maintained in the extra-tropical zones, more by *parallel* than *superposed* currents, that these currents had a shifting transverse or lateral motion, and in consequence, so to speak, they advanced "sideways." I am not aware that Professor Dove connected these shifting parallel currents with barometric phenomena, although he did with thermometric. In the course of my investigations into those phenomena termed atmospheric waves, I ascertained, by carefully discussing the records of the wind for the greater portion of November 1842, that not only such parallel compensating currents existed as stated by the Professor, but that during the period under inquiry, a similar system of parallel and compensating winds were blowing and moving at right angles to them. The arrangement of these *cross* winds was N.E.—S.W. and N.W.—S.E. I also found that these winds were intimately connected with barometric pressure, so that when the barometric curve was projected and presented the wave form, the mind was led to group under the general term "atmospheric wave," at least *two* if not three distinct classes of phenomena. First, the winds succeeding one another, as we know they do with more or less regularity. Second, the pressure, a more or less continuous fall of the barometer generally succeeding a gradual and continuous rise: both these phenomena are capable of being represented by curves, the rising barometer mostly coinciding with the decreasing force of wind, and the falling barometer with its increase, so that a rising and falling curve will with more or less fidelity represent the passage over a station or a tract of country of the two compensating currents of Dove. It is not the mere rise and fall of the barometer, as such, that constitutes an atmospheric wave; the barometric curve itself is doubtless the complex result of two or more distinct variations of pressure connected with variations of wind as above. When these are disentangled, the mind is able to grasp the onward march of the two parallel winds, accompanied by their respective pressures; so that true waves of pressure really, I apprehend, sweep over a country; and applying the wave nomenclature, low pressures have been characterized as troughs and high pressures as crests.

As illustrative of these remarks, I beg to exhibit on this occasion the most complete instance of opposite pressures that has come under my notice; it is the opposite barometric curves at Alten and Lougan during the early part of November 1842: the curves will be found on page 39, 'Report,' 1848. I am indebted to Dr. Lee for the observations furnishing the curve at Alten.

Observations on the Meteorological Phenomena of the Vernal Equinoctial Week. *By* M. Du Boulay.

The author has been engaged for the long period of thirty years in endeavouring to ascertain whether there could be traced in the winds or weather prevailing about the equinox, in any given locality, a connexion with, or resemblance to, the winds and weather generally prevailing during the ensuing summer in the same locality. He infers from his observations that such is the case, and that the probable character of the summer in England may be predicated about the 25th of March, by noting the weather in the equinoctial week then just ended. He gave examples in support of his views.

On the Effect of a Rapid Current of Air. *By* R. Dowden.

On British Storms, illustrated with Diagrams and Charts.

By Admiral FitzRoy, *F.R.S.*

It is well known that no year passes in which the British islands are not visited by storms, and that they vary in degree of force from what seamen call a gale to a hurricane irresistible in violence. Only of late years, however, has it been supposed, and but recently proved, that nearly all, if not indeed the whole, of these remarkable tempests, by which a very notable amount of injury has been done, have been so much alike in character, and have been preceded by such similar warnings, as to warrant our reasoning inductively from the well-ascertained facts, and thence inferring laws. Every one looks back to some extraordinary storm as exceeding all others in his lifetime; but a tempest that is severely felt in one part of the country is not always extensive, but usually the reverse,—more or less limited in area, varying in range, direction, and force. It would be tedious to advert to some of even the most devastating tempests in much detail, therefore I propose to take three only as types, and glance summarily over their most marked features, hoping that the diagrams suspended around or lying on the table will supply enough additional facts. The first storm to which I would ask attention in passing is that so well and so fully described by De Foe, in 1703. He calls it (page 11) "the greatest, the longest in duration, the widest in extent of all the tempests and storms that history gives any account of since the beginning of time. . . . . Our barometers," he continues, "informed us that the night would be very tempestuous; the mercury sank lower than ever I had observed it on any occasion" (page 25); it fell to 28·47 (page 30). This storm began at south and veered through the west towards north, round to the south, and then continued between south-west and north-west, with more or less strength, for a whole week! Very remarkable it is that not only did De Foe suppose this storm began near the southern coast of North America, but that it traversed England, France, and the Baltic, to lose itself in the Arctic regions. He recurs afterwards to its shifting from south-west to north-west, and coming from the west like other storms in the south of England, but does not advert to any corresponding north-easterly wind, nor had he evidently any idea of a rotatory or circulating atmospheric current. Probably accounts from the north of England were much less attainable then; but it is noted that the north of England escaped the violence of that storm. I cannot now take more from De Foe, but venture to say that his graphic accounts of many storms, and the more comprehensive views of Dampier, are well worth the notice of even scientific meteorologists. To Franklin, Capper, Redfield, Reid, and Dove, besides other authorities, seamen may well be grateful; for their works, and those compiled from them, are facts and inferences at present trusted because demonstrated to be indisputably true.

It is now necessary that other storms should be noticed, and in a much more precise manner; but two alone will probably suffice as types. The 'Royal Charter' gale, so recent in our recollection, so remarkable in its features, and so complete in its illustrations, I may say, from the fact of its having been noted at so many parts of our coast, and because the storm passed over the middle of the country, is one of the easiest to deal with which has occurred for some length of time. I would therefore ask for a few minutes' attention to this particular instance. There are four diagrams among those on the wall which refer particularly to the 25th and the

26th of October last. Referring to the charts and the diagrams, it will be seen that the lowest barometer and a corresponding or simultaneous *lull* prevailed over ten, fifteen, or twenty miles successively in the direction I have pointed out. But at the time that this comparative lull existed, there was around this central space what by some is called a vortex, but can hardly be appropriately termed a vortex, because there was no central disturbance: there were only variable winds or calm for a short time in the middle of this space, which was about ten or fifteen miles across. The wind obtained a *maximum* velocity of from sixty to one hundred miles an hour, at a distance of twenty to fifty miles from this comparatively quiet space, and in successive meteoric eddyings crossed England towards the north-north-east, the wind blowing from all points of the compass around the lull, so that while at Anglesea the storm came from the north-north-east, in the Straits of Dover it was from the south-west; on the east coast it was easterly; in the Irish Channel it was northerly, and on the coast of Ireland it was from the north-west. The charts show that there was a similar circulation, or cyclonic commotion, going or passing northwards from the 25th to the 27th, being two complete days from the time of its first appearance in (what is called) "the chops of the Channel," while outside of this circulation the wind became less and less violent; and it is very remarkable that, even so near as on the west coast of Ireland, they had fine weather, with light winds, while in the British Channel it blew a northerly and westerly gale. At Galway and at Limerick on that occasion there were light winds only, I repeat, while over England the wind was passing in a tempest, blowing from all parts of the compass around a central similar "lull." The next storm that occurred was similar in its features, though it came from a slightly different direction. This storm was on the 1st and 2nd of November, and its character was in all respects like that just described, now usually called the "Charter Gale." It came more from the westward, passed across the north of Ireland, the Isle of Man, the north of England, and then went off across the North Sea towards Denmark. Further than that distance facts have not yet been gathered; but, no doubt, in the course of a few months they will be.

The general effect of these storms fell unequally on our islands, and less inland than on the coasts. Lord Wrottesley has shown, by the observations made at his Observatory in Staffordshire, that the wind is diminished or checked by its passages over land; and looking to the mountain ranges of Wales and Scotland, rising 2000, 3000, or 4000 feet above the level of the sea, we see they must have great power to alter the direction, and probably the velocity of wind, independently of the alterations caused by the changes of temperature. The very remarkable similarities of this storm of the 1st and 2nd of November and that of the 25th and 26th of October, the series of storms investigated by Dr. Lloyd during ten years, and the investigations of Mr. William Stevenson in Berwickshire, require especial notice on this occasion. There is no discrepancy between the results of the ten years' investigations published by Dr. Lloyd in the Transactions of the Irish Academy, the three years' investigations published by Mr. W. Stevenson, and all the investigations which have been brought together during the last four years. They all tell the same story. Dr. Lloyd only found in ten years one instance even of a partial storm which differed; namely, one storm that came from the north in the first instance. Storms from the south-west are followed by sudden and dangerous storms from the north and east; and these storms from the north and east do much damage on our coasts. Upon tracing the facts, it is proved that the storms which come from the west and south come on gradually, but that storms from the north and east begin suddenly, and often with extraordinary force. The barometer, with these north-eastern storms, does not give so much warning upon this coast, because it ranges higher than with the wind from the opposite quarter. But though the barometer does not give much indication of a north-east storm, the thermometer does; and the known average temperature of every week in the year affords the means at once, from the temperature being much above or below the mean of the time of the year, of showing whether the wind will be northerly or southerly (thanks to Mr. Glaisher's Greenwich observations).

Now to revert to a few of the signs which preceded the 'Charter gale.' For a few days before that storm came on, the thermometer was exceedingly low in a great part of the country; there were north winds in some places, and a good deal of snow; but nothing else extraordinary. There had been a great deal of exceedingly dry and hot weather previously. These facts, of course, require consideration, but not now. I may just mention, that over our islands, and especially in the north of Ireland, at that time, on the 22nd and 23rd of October, barometers were very low. Many days preceding the 'Charter storm,' an extraordinary clearness in the atmosphere was noticed in the north of Ireland—the mountains of Scotland were never seen so prominently as they were in the few days preceding those on which the great storm took place. Every one is aware that last summer was remarkable for its warmth: it was exceedingly dry and hot. All over the world, not only in the Arctic, but in the Antarctic regions, in Australia, South America, in the West Indies, Bermudas, and elsewhere, auroras and meteors were more or less prevalent, and they were more remarkable in their features and appearances than had been noticed for many years. There was also an extraordinary disturbance of the current along the telegraph wires. They were so disturbed at times, that it was evident there were great electric or magnetic storms in the atmosphere which could be traced to no apparent cause. Lord Wrottesley, in his Address, adverted to some extraordinary facts respecting various circulating substances apparently absorbed by the sun. Perhaps these electric disturbances were connected with the peculiar action of the sun upon our atmosphere. Electrical wires above ground, as well as submarine wires, were unusually disturbed, and these disturbances were followed within two or three days by great commotions in the atmosphere, or by some remarkable change.

I will now refer to another subject—the question of areas or lines of barometric pressure. Professor Espy, of the United States, contends for a long line from north to south, or from one direction straight to another, and not only Espy but also some among our own countrymen. The principal object of making these sections, as it were soundings, of the atmosphere, shown in the diagrams, was to prove whether lines of pressure, or whether areas of pressure prevailed; and I think, when they are all closely looked into, they go to prove that while the atmosphere in the British islands varied in its pressure from time to time, such variation was not on a particular line, but extended over a large area. Before I leave this part of the subject, I may say, as some of the remarkable exceptions to the force of these particular storms, that at some places there was little or no wind; the barometer fell much, but there was no storm, for the wind circulating around these districts did not affect them, while at other places the storm was tremendous. It has been often asked whether the ship that was lost—the 'Royal Charter'—might have been saved; and I will give an instance of what another ship did which took ordinary precautions on that night. Whether the 'Royal Charter' did take the right course it is not for me to say, but I hold in my hand the details of another kind of management within ten miles of the 'Royal Charter' that night. The commander of this vessel, a sailing-ship and not a steam-ship (the 'Royal Charter' had the double advantage), was guided by the instructions laid down by Capt. Maury, who has treated the subject of winds in a practical manner, and has brought together a large amount of useful information; and although, as I am aware, he occasionally theorises when he has not facts enough for philosophy, as a practical man he has been guided by plain principles, intelligible to seamen generally. Unquestionably, Maury has brought together a great deal of valuable information, and made it generally available. The following paper has come into my hands within the last few days very opportunely:—

"Having had many threatenings of bad weather for several days past, I began to apply your views as to storms; and not having much sea-room, I considered them more closely. For three or four days before the 26th of October, we had very squally weather, with frequent sharp flashes of lightning from east to north-east. During the night of the 24th, I stood to the northward, and till noon of the 25th, with the wind strong from east-north-east. At noon I tacked, thinking that if the gale should come on, I might take the off-shore tack in the night, and have the vortex of the gale to the south-eastward. I stood on, therefore, till half-past five P.M., and then wore ship under short sail, when in a line with Holyhead and Bardsey, about ten miles or so distant from Holyhead, as near as I could judge, being thick and dark. At eight P.M., gale increasing, I took in close-reefed main topsail, and fore topmast stay-sail, having nothing then set but the main spencer and a small storm-mizen. It blew a complete West-India hurricane, but I drove *off-shore*, and I thought the force of the storm did not increase. I now think, from what other ships suffered which were to the northward of me at the same time, that further from me it blew harder. I did not suffer *any damage whatever* more than usual in ordinary blows; only a little chafe and some spray. The lightning alluded to above was very unnatural in its appearance, being of such a sharp flashing glare, without leaving off. Unless looking at the exact place of its flash, you could not tell from where the light actually came.

(Signed) "WILLIAM J. JOHNS, Commanding the Ship."

"*William Cumming, U. S.*"

These two instances are important; one of a ship managed in accordance with instructions published for seamen, being saved, while the other, which adopted a different course, was lost. There is one special instance on which not only private but public interests were at stake, and where the ship to which I allude was seriously injured. There was one of Her Majesty's ships, a 90-gun ship, fitted up with steam-engine and other appliances, in the Atlantic, in the early part of October last. That ship had very bad weather near the edge of the Gulf-stream. A succession of circling storms occurred, and in every instance the ship was managed in direct opposition to the known laws of storms, was considerably damaged, and obliged to *return*. Now, that is a fact which ought not to have occurred in the British Navy at the present day. It might have been that there was some reason for such usually incorrect proceeding in one instance; but that there should have been any reason in three successive instances is more than we can conceive: any one can estimate the amount of expense caused by a ship so brought back to England from her destination. The simple rule of seamanship is when facing the wind the centre of the storm will be to the right or on the *right hand*, therefore you should go to the left. In the southern hemisphere the centre is on the *left hand*, and you must go to the right. supposing that sea-room and circumstances enable you to choose. But these simple results are the consequence of very great consideration on the part of scientific persons,—particularly Sir W. Reid, Redfield, Capper, Espy, Dr. Lloyd, and others,—especially those in India, who have done so much, viz. Piddington and Thom. In this country no one has effected more than Sir W. Reid, who collected together all that had been done for many years, and published in a clear manner the results of his accumulated investigations. A very remarkable storm has been lately traced by Mr. Rowell, of Oxford, and his description published within the last few days. This storm occurred near Calne in Wiltshire, cutting through fields and trees, and in one place actually lifted a broad-wheeled waggon *from the road over a hedge into the next field*! The violence of the wind was confined to a limited line. The downward and onward pressure of the wind was so great in that locality, that it acquired such elasticity as to lift opposing weights and carry them on. I have known such things myself. I have known the wind lift a boat into the air and shake it to pieces. We have all heard of houses being unroofed, of trees torn up by the force of the wind; but this is the first time I have heard of a heavy waggon being lifted up and hurled over a hedge.

I will only venture to make one or two observations in reference to the theory of these subjects. Dove, in his work, shows how currents of wind, parallel currents, as he calls them, co-exist. A great polar current coming from the north and east is passing in one direction, while a current from the tropical regions is going in the other direction, nearly opposite; but to follow the theoretical considerations of how these great currents move from the Arctic regions towards the tropics and return to the Arctic regions, is a subject too large for the present limited time. Dove has shown most clearly in his work (which is translated into English), that circulation of the atmosphere in great polar and equatorial or tropical currents, prevail not only in our hemisphere, but everywhere. I can bear witness that his reasonings and particular views can be corroborated in every part of the world.

The British Association has made application to Her Majesty's Government to authorize arrangements for communicating warning of storms from one part of the country to the other; and, in conclusion, I will read the details of that arrangement which promises to be so beneficial. Arrangements have been authorized by the Board of Trade (under a minute from the President, dated June 6), in consequence of which a daily and mutual interchange of certain limited meteorological information will be transmitted between London and Paris, the results of five subsidiary communications to the central stations of Paris and London. Authority being thus given to collect and communicate, by the telegraph, particular meteorological intelligence, a commencement may be made on the 1st of September, as the plan proposed is simple, and the machinery is ready. Once a day, at about nine A.M., barometer and thermometer heights, state of weather, and direction of wind will be telegraphed to London, from the most distant ends of our longest wires,—namely, Aberdeen, Berwick, Hull, Yarmouth, Dover, Portsmouth, Jersey, Plymouth, Penzance, Cork, Galway, Londonderry, and Greenock. Facts sent thus from five of these places, will be put into one telegram, and sent to Paris immediately, when a corresponding communication will be made from the southward Atlantic coasts. When threatening signs are not apparent, no further notice will be transmitted to or from London on that day, respecting weather. But when indications are such as to warrant some cautionary signal at a certain part of, or along all our coasts, the words "Caution,—North" (or "South") will be sent to some of the thirteen places specified, or to all of them, on the receipt of which a cone (or triangle) will be hoisted at a staff (point up for north, down for south), indicating the side whence wind may be expected. This signal will be repeated along part of the coast by the Coast Guard, at such of their stations as may be authorized (at most of their stations flagstaffs are visible to coasters). Danger will be implied by a drum (or square), a cone, and perhaps, in addition, very great danger by a cone, a drum, and a second cone. [The cones and drums may be made with hoops and black canvas, to collapse, without top or bottom. They will be the same in shape from all points of view, and unlike any other signal, such as a time-ball, used ordinarily.] As the Coast Guard extends all along the frequented parts of our shores, and as the telegraph companies are liberally willing to have instruments and signals placed at their extreme stations, in charge of and used by their officials, only the necessary materials and instructions will be required, all of which are ready or in progress. By vigilance at the central station, and by taking great care to avoid signalling too frequently, much may be done towards diminishing the losses of life on our increasingly crowded coasts. Property alone may be duly *insured*, but every wise precaution for the safety of life should, of course, be used. As an auxiliary measure, a concise Manual of Instructions for the Barometer will be circulated among maritime communities; who, though they may have frequent access to "weather-glasses" of various kinds, do not generally know how to use them most advantageously. The following details may be useful, as well as interesting, to those who wish to investigate these subjects and examine the diagrams more critically:—The probable limits of error of the barometric curves on the synoptic sheets, 21st of October—2nd of November 1859. The observations at the regular observatories, such as Greenwich, Oxford, Cambridge, Highfield House, Kew, &c., have had all corrections applied, and have been reduced to sea-level, and the temperature of 32°. The returns from members of the British and Scottish Meteorological Societies (nearly ninety in number) have nearly all been corrected for the exact height above sea-level, all within a few feet. The corrections due to instrumental errors and reduction to 32° have (in most cases I believe) been applied by the observers. The Continental observations have been collected partly from the Dutch papers and partly from the 'Moniteur.' Those from the former have been reduced to 32°, and, it may be presumed, have also been corrected for instrumental errors. The heights of some stations are known; the corrections due to those heights have been applied, and others are known to be little, if at all, above the sea-level. Any error in laying down a curve from such data can scarcely exceed two or three hundredths of an inch. The observations obtained from the 'Moniteur' it is assumed are given duly corrected. The heights of the stations of ordinary observers are known for the most part pretty nearly, and corrections for such heights have been applied to the returns. Other corrections have only been applied in a few cases—observations sometimes recorded only to the nearest tenth, not being deemed worthy of any further correction. Those returns, however, of which the barometrical observations are evidently erroneous (from comparison with other more reliable neighbouring and contemporaneous obsevations), have been rejected altogether. On the whole, we may safely assume that even these observations, as laid down, are less than a tenth in error. The heights of the lantern above the sea-level and of the tower, from the base to the vane, being known, the probable height of the barometer can be ascertained. The proper correction for the height thus estimated has been applied, and all returns suspected of being erroneous rejected.

On the Similarity of the Lunar Curves of Minimum Temperature at Greenwich and Utrecht in the Year 1859. *By* J. PARK HARRISON, *M.A.*

The author showed that, on the mean of twelve lunations, in 1859 the greatest amount of cold displayed itself at both the above-named stations between full and new moon: the difference between the mean minimum temperatures of the first and second halves of the lunation at Greenwich being 2°·4; at Utrecht 2°·0. There were two minima for night temperature both at Greenwich and Utrecht; they followed on full moon and last quarter. The least amount of cold was at first quarter. The difference between the minimum temperatures at first quarter and shortly after last quarter, on a mean of twelve observations taken at both stations, was nearly 7°. The difference in the means of the mean temperature of the day for forty-three years for the two periods of fourteen days, at the former place had been previously found to be 1°·1.

Mr. Harrison expressed increased conviction that effects so contrary to expectation must be due to the presence or absence of cloud, or to its height above the earth,—to whatever cause this phenomenon may ultimately be assigned.

On the Principles of Meteorology. By Professor HENNESSY, *F.R.S.*

The author contended that the principal object of meteorology was the prediction of the weather within certain probable limits. The great complication of atmospherical phenomena, and the influence of remote causes of disturbance, would undoubtedly render this extremely difficult. Although the atmosphere is itself one of the best examples of an unorganized body to which we could refer, yet its complicated and fluctuating phenomena suggest to us the mode in which such phenomena should be investigated. Any success could be expected only by treating the atmosphere very nearly as an organized body, and studying its abnormal conditions with the same continuity and generality of observation as is usually employed in physiology. Observations made at stated hours have been found by themselves rarely capable of affording means to foretell the future conditions of the weather for even short periods of time. A careful study of the appearances of the sky, such as has been so long familiar to mariners and others interested in the conditions of our atmosphere, would, when made by men well prepared with preliminary knowledge of the principles of physical science, throw far more light upon the chief object of our search. Mr. Hennessy illustrated this remark by referring to some such observations which he had made during the month of June. Although he had at first considerable scepticism as to the possibility of obtaining correct results from the continuous photographical registration of atmospherical conditions, Mr. Hennessy was satisfied, from what he had witnessed during 1856 in the Radcliffe Observatory, that such a system was not only possible, but that it sometimes disclosed important changes which would have escaped the method of observation at stated hours. He instanced the connexion between the phenomena of thunder-storms and sudden barometric depressions, as pointed out by the late Radcliffe Observer at the Glasgow Meeting, and the connexion between days of great solar irradiation and minute vertical atmospheric currents, as pointed out by himself*. He concluded by pointing out the manner in which, from the increasing knowledge we possess of the influence of the ocean upon climate, the greater stability of its currents, compared to those of the atmosphere, may under the peculiar conditions of the British islands enable us to foresee many important changes within comparatively extended periods of time†.

On Antarctic Expeditions. By Captain MAURY, *U.S. Navy.*

Observatory, Washington, 20th May, 1860.

MY DEAR LORD WROTTESLEY,—I hope the time is not far distant when circumstances will be more auspicious than at present they seem; for, as soon as there appears the least chance of success, I shall urge the sending from this country an exploring expedition to the eight millions of unknown square miles about the South Pole. I hope that my letter to you upon the subject was sufficiently clear to satisfy your mind, and conclusive to enlist your influence with Her Majesty's Government and the English people in the cause of Antarctic exploration. It is an enterprise in which the British nation may well take the lead, for it is nearer to them than to the rest of the world. There is Melbourne, your great commercial mart, that is already, in amount of shipping, a rival of Liverpool. It is within less than two weeks' run by steamer from the borders of this unknown region. So, you observe that these eight millions of unknown square miles lie at your door, and the responsibility of permitting them so to lie longer will lie there too. "You go; we'll come." An expedition might be sent from Australia with little or no risk. Two propellers, or even two vessels with auxiliary steam-power, might be sent out, so as to spend *our* three winter months in looking for a suitable point along the Antarctic Continent to serve as a point of departure for over-land, or over-ice parties. Having found one or more such places, vessels, properly equipped for land and ice and boat expeditions, might be sent the next season, there to remain, seeking to penetrate the barrier, whether of mountain or of ice, or both, until the next season, when they might be relieved by a fresh party, or return home to compare notes, and be governed accordingly. You know the barometer at all those places which have a rainy and a dry season, stands highest in the dry, lowest in the wet. Now, I do not find any indications that the Antarctic barometer has months of high range: it is low all the year. Therefore—if I be right in ascribing the apparent tenuity of the air there to the heat that is liberated during the condensation of vapour, from the heavy precipitation that is constantly taking place along the sea front of those "barriers"—we should be correct in inferring that the difference in temperature between the Antarctic summer and winter is not very marked. If, in a case like this, we might be permitted to indulge the imagination, we might fancy the "barrier" to be a circular range of mountains, and that beyond these lies the great Antarctic basin. Beyond this range, as beyond the Andes, we may fancy a rainless region, as in Peru,—a region of clear skies and mild climates. Though the air in passing this range might be reduced below the utmost degree of Arctic cold, yet being robbed of its vapour, it would receive as sensible the latent heat thereof. Passing off to the Polar slope of these mountains, this air then would be dry air; descending into the valleys, and coming under the barometric pressure at the surface, it would be warm air. Leslie has explained how, by bringing the attenuated air down from the snow-line, even of the tropics, and subjecting it to the barometric weight of the superincumbent mass, we may raise its temperature to intertropical heat by the mere pressure. In like manner, this Antarctic air, though cold and rare while crossing the "barrier," yet receiving heat from its vapours as they are condensed, passing over into the valleys beyond, and being again subjected to normal pressure, may become warm. We have abundant illustrations of the modifying influences upon climate which winds exercise after having passed mountains and precipitated their vapour. The winds which drop the waters of the Columbia river, &c. on the western slopes of the Rocky Mountains, make a warm climate about their base on this side, so much so that we find in Piedmont Nebraska the lizards and reptiles of Northern Texas. Indeed, trappers tell me that the Upper Missouri is open in fall long after the Lower is frozen up, and in spring long before—several weeks—the ice in the more southern parts has broken up. The eastern slopes of Patagonia afford even a more striking illustration of climates being tempered by winds that descend from the mountains, bearing with them the heat that their vapour has set free. Thus you observe, that an exploring party after passing the barrier *might*, as they approach the pole, find the Antarctic climate to grow milder instead of colder. It would be rash in the present state of our information to assert that such *is* the case; but that such *may* be the case should not be ignored by the projectors and leaders of any new expedition to those regions. The existence of an open sea in the Arctic ocean has, with a great degree of probability, been theoretically established. But the circumstances, as strong as they are, which favour the existence of an open water there, are not so strong and *direct* as are the proofs and indications of a mild *polar* climate in the Antarctic regions. I have examined the immense library of log-books here for the lines of Antarctic ice-drift. There appear to be two, both setting to the north-east, one passing by the Falkland Islands, the other having its northern terminus in the regions about the Cape of Good Hope. Further south, icebergs are found all around; but in these lines of drift they are found nearest the equator. The space between the Falkland drift and the Good Hope drift is an unfrequented part of the ocean. It may therefore be one broad drift, the edges of which only I have pointed out. The most active currents from the south do not run with this ice. Humboldt's current is the most active, but it does not get its icebergs as far north as they come by these lines. This circumstance has suggested the conjecture that one part of the Antarctic Continent must be peculiarly well situated for the formation of glaciers and the launching of icebergs. These lines of drift point to such a place. The facts stated in my former letter will, I trust, when considered in connexion with these views, impress you with the importance of the subject. So, trusting, and hoping that you will join with me in the cry, "Ho for the South Pole!"

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* Report for 1858, Trans. Sect. p. 36.

† Report for 1859, Trans. Sect. p. 50. Proceedings of the Royal Society, vol. ix. p. 324. Atlantis, vol. i. p. 396. Philosophical Magazine, April 1846, and October 1858.

On the Climates of the Antarctic Regions, as indicated by Observations upon the Height of the Barometer and Direction of the Winds at Sea. By Captain MAURY, *U.S. Navy.*

In the course of my labours connected with the wind and current charts, I had caused to be grouped 1,213,933 observations upon the direction of the wind at sea. Each one of these observations embraces a period of eight hours, and aims to give the prevailing direction of the wind during that time. Thus each individual of my group is, in fact, itself the mean of many. The result of the whole is presented diagrametrically in Plate I., in which the mean direction of the wind in each belt, and for the four quarters, is represented by the arrows correctly, both as to mean direction and average duration.

From the labours of Lieut. Andrau and his colleagues at the Meteorological Institute of the Netherlands *, I obtained 83,332 observations upon the barometer between the parallels of 50° N. and 36° S. at sea. This fine series was enriched by the observations at Greenwich, St. Petersburg, and Hobart Town on shore, and by Dr. Kane, Sir James Clark Ross, and Lieut. Wilkes at sea, during their Arctic and Antarctic explorations. From these the barometric profile of the atmosphere (Plate I.) was constructed.

The barometric observations on shore were not found in all cases to accord with those at sea. Moreover, those of Wilkes and Ross were the means of observations for only a few days.

Our 'Marine Magazine,' as the precious store of abstract logs may be called, contained many more, and which, by their great numbers, and in consequence of their having been made at all seasons of the year, would afford better mean results. In extension of Andrau's series, I therefore added 6945, between the parallels of 40° and 60° south, from the log-books of this office. These, Andrau's, and Dr. Kane's in the ice, form the elements of the Barometric Curve, Plate II.

Proceeding upon the supposition that, with regard to the general movements and the mean status of the atmosphere, we should have at sea the rule, on land the exceptions, I commenced to group these observations for discussion.

As the North Indian Ocean, the China and West India seas, where the monsoons blow, are known to present exceptional cases to the general movements of the winds at sea, the observations for them were excluded from the general summing up.

Thus premising, the winds were taken from the pilot charts and grouped in belts 5° of latitude broad. As a rule, the vessels that are cooperating with us seldom go on the Polar side of 60° north or south; for our fleet of observers consists for the most part of merchantmen, whom the channels of trade do not carry beyond these parallels; consequently the observations of the winds were arranged in 24 belts (12 on each side of the Equator); all the observations between the Equator and 5° north, for example, being in one belt; and so on for every 5° of latitude.

Now, considering that the general movements of the atmosphere, as exhibited by the winds at sea, are to and fro between the Equator and the Poles, all these observations were arranged in two groups for each belt, and classed either as winds with *northing*, or as winds with *southing*, in them, as per Table, showing the average annual duration in days of winds.

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* Maandelijksche Zeilaanwijzingen van Java naar Het Kanaal. Als Uitkomsten Wetenschap en Ervaring Aangaande Winden en zeestroomingen in sommige Gedeelten van den Oceaan Uitgegeven Door Het Koninklijk Nederlandsch Meteorologische Instituut. Utrecht, 1859.

Winds with Northing, and Winds with Southing in them.

Belts.	Northern Hemisphere.					Southern Hemisphere.				
	No. of observations.	Northing.	Southing	Excess in days.		No. of observations.	Northing	Southing.	Excess in days.	
		Days.	Days.	North.	South.		Days.	Days.	North.	South.
Between 0° & 5°	67,829	79	268	...	189	72,945	83	269	...	186
5 & 10	36,841	158	183	...	25	54,648	72	283	...	211
10 & 15	27,339	278	73	205		43,817	82	275	...	193
15 & 20	33,103	273	91	182		46,604	91	266	...	175
20 & 25	44,527	246	106	140		66,395	128	227	...	99
25 & 30	68,777	185	163	22		66,635	147	208	...	61
30 & 35	62,514	155	195	...	40	76,254	150	204	...	54
35 & 40	41,233	173	179	...	6	107231	178	178	0	0
40 & 45	33,252	163	186	...	23	63,669	202	155	47	
45 & 50	29,461	164	189	...	25	29,132	209	148	61	
50 & 55	41,570	148	203	...	55	14,286	208	151	57	
55 & 60	17,874	142	213	...	71	13,617	224	132	92	

It thus appears that we have, as we already well knew, in each hemisphere a medial belt—a barometric ridge in the air—from which the prevailing direction of the wind on one side is towards the Equator, and from the other towards the Pole. In the southern hemisphere this ridge is sharp, being included between the parallels of 35° and 40°; in the northern hemisphere, however, it seems to be less sharply defined, for the debateable ground, or belt, within which neither wind appears to have a very marked ascendency as to prevalence, extends from lat. 25° to 50° N.

Proceeding from these belts towards the Equator, equatorial-bound winds become more and more prevalent; or if we proceed towards the Pole, the polar-bound winds become more and more prevalent,—thus indicating the existence both near the Equator and in the polar regions of a permanent degree of aërial rarefaction sufficient to produce an indraught from a medial line or belt towards each.

To ascertain the degree of rarefaction about the Poles, as far as the observations on the barometer at sea would indicate a result, the Barometric Curve (Plate II.) was constructed from the data expressed in this Table, showing

The Mean Height of the Barometer.

Latitude.	Barometer.	No. of observations.	Latitude.	Barometer.	No. of observations.
0° to 5° N.	29·915	5114	0° to 5° S.	29·940	3692
5 to 10 „	29·922	5343	5 to 10 „	29·981	3924
10 to 15 „	29·964	4496	10 to 15 „	30·028	4156
15 to 20 „	30·018	3592	15 to 20 „	30·060	4248
20 to 25 „	30·081	3816	20 to 25 „	30·102	4536
25 to 30 „	30·149	4392	25 to 30 „	30·095	4780
30 to 35 „	30·210	4989	30 to 36 „	30·052	6970
35 to 40 „	30·124	5103	40 to 43 „	29·88	1703
40 to 45 „	30·077	5899	43 to 45 „	29·78	1130
45 to 50 „	30·060	8282	45 to 48 „	29·63	1174
78° 37′ „	29·759	Dr. Kane	48 to 50 „	29·62	672
			50 to 53 „	29·48	665
			53 to 55 „	29·36	475
			56½ „	29·29	1126

It would seem from this curve, which by its regularity shows the observations at sea to be remarkably accordant, that the atmosphere is much more attenuated in austral than in boreal regions; and that the high barometer, with the light airs and baffling winds of the tropical calm belts, is the dividing atmospherical ridge, so to speak, between the low barometer about the Pole on one side and near the Equator on the other; and that the position of this ridge is determined by the degree of polar in contrast with the degree of equatorial rarefaction. The trade-winds rushing in on one side, and the counter trades on the other—as the polar-bound winds may be called—supply the indraught for these places of attenuated air and low barometer.

It thus appears that the equatorial calm belt is a sort of thermal adjustment between the calms of Cancer and Capricorn; which in turn are in adjustment to the dynamical power of the ascending columns of air in the equatorial and polar calm places.

The low barometer off Cape Horn has long attracted the attention of navigators. The low barometer in other longitudes south caused Wilkes, Ross, and others, to remark upon the diminished pressure in high southern latitudes, and upon the apparent inequality in the distribution of the atmosphere north and south of the Equator.

The barometric observations between 40° and 60° South, and which are quoted in the preceding Table, were collected in three groups—first, from the logs between the Cape of Good Hope and Australia, next from Australia to 80° West, and then about Cape Horn. The result showed that a low barometer is not peculiar to Cape Horn regions, but that it is general and circumferential in austral latitudes, diminishing rapidly as we approach the Pole.

The great extent of the austral water surface, with the vapour with which it keeps the "brave west winds" of these regions loaded, and the heat which with the condensation of these vapours is liberated there, suggests the cause of this low barometer.

If it be the vapour and the liberation of its latent heat that cause the permanent expulsion from Antarctic regions of so much of the atmosphere as this curve and these observations indicate, then should we not follow the argument up, and infer that the extreme cold of the Antarctic climate is by no means so severe as that of the north?

The unexplored regions of the south embrace an area of more than eight million square miles, or about one-sixth of the whole extent of the dry land surface that is contained on our planet.

Since the attempts to penetrate those unknown regions, steam has been introduced upon the ocean, and the modern explorer has at his command a power which enables him to defy wind and tide. Hygiene on board ship has been so improved, that the sailor may now keep the sea for almost an indefinite period of time. The invention, the discoveries, and the improvements of the age, place in our hands the means of fitting out Antarctic expeditions, and of endowing them with powers that would have made any previous expedition there doubly effective.

Under these circumstances, would it not be a reproach upon the Christian nations, and especially upon those great governments who have agreed to unite in a common plan of physical research at sea, if so large a portion of the earth's surface were permitted to remain unexplored?

Plate III. shows the furthest reach of Antarctic exploration. The tracks of Antarctic explorers, from Cook down to the present day, go to make up these limits.

It is not the object of this paper to elaborate the views suggested by the observations offered with this paper; but rather to present the observations themselves, with such explanation as seemed necessary to enable others to understand them.

If I have succeeded in doing this, all who will take the trouble to study them will find them very suggestive. M. F. MAURY.

Observatory, Washington, 11th May, 1860.

On the Cause of the Descent of Glaciers. By the Rev. HENRY MOSELEY, *F.R.S., Canon of Bristol, Inst. Imp. Sc. Paris Corresp.*

The fact of the descent of a body, when placed upon an inclined plane, due to the variations in its temperature, first observed in the descent of the lead which covers the south side of the choir of Bristol Cathedral, and communicated by me to the Royal Society in the year 1855, I have since confirmed by the following experiment. I fixed a deal board, 9 feet long and 5 inches broad, to the south side of my house, so as to form an inclined plane, and upon it placed a sheet of lead, turning its edges down over the edges of the board, and taking care that it should not bind upon it, but be free to move with no other obstruction than that which arose from its friction. The inclination of the board was 18° 32′, the thickness of the lead was one-eighth of an inch, and its weight 28 lbs. The lower end of the board was brought opposite to an upper window, and a "vernier" was constructed which could be read from within, and by which the position of the lead upon the board could be determined to the 100th of an inch. I began to measure the descent of the lead on the 16th of February, 1858, and recorded it every morning between seven and eight o'clock, and every evening between six and seven until the 28th of June.

The lead had descended between the 16th of February and the 30th of April (a period of seventy-four days) 10·61 inches, being an average daily descent of ·1433 inch. On the 4th of May it was drawn up the board again to its first position. Between that date and the 28th of June (a period of fifty-five days) it had descended 11·97 inches, being an average daily descent of ·2176 inch. Its descent was far from uniform, being on some days scarcely (if at all) perceptible, and on others amounting to nearly half an inch. The *average* daily descents in successive months from February to June were in

	inch.
February	·10000
March	·13806
April	·16133
May	·21500
June	·21888.

Every variation in the temperature of the lead contributed to its descent. The extreme temperatures of the day and the night could not therefore determine its daily motion; for with the same extremes of day and night temperature, there may be great differences in the number and amount of the intervening variations of temperature. It is the effect of these daily *variations* of temperature, up and down, by which the descent of the lead totalizes. Although, therefore, we are to look for the influence of the extremes of day and night temperature upon the daily descent, we are also to look for that of the variations between each two extremes. I accordingly remarked that it was on days when a thermometer in the sun varied its height rapidly and often, that the lead descended most. On the contrary, when the sky was open and the heat advanced and receded uniformly, the descent was less, although the difference of the extreme temperatures might be greater. It was least of all when there was continuous *rain*. During the night the descent of the lead was often imperceptible. I have explained the descent of the lead in a paper published in the 'Proceedings of the Royal Society' for April 1855.

If we suppose the sheet of lead to become ice, and its dimensions to be increased 20,000 times, and if for the board on which it rests we substitute a mountain side lying at a slope of 18½°, we shall have a glacier 1½ mile broad, 200 feet deep and 34 miles long, and which in no other respect than as it regards its *length* will be an exaggeration. By converting the lead into ice, its physical properties will, however, have been in some important particulars changed. It will have become twice as dilatable as lead is, that is, it will dilate twice as much by a given variation of temperature when unopposed as lead does*. It will have become a more elastic substance than lead is, that is, it will be capable of overcoming a greater force opposed to its dilatation under a given change of temperature. It will have lost its ductility and have become friable, that is, its parts will have become more liable to separation from one another and its mass to disintegration. But, together with the last-mentioned quality, it will have acquired the property (called regelation) of easily, and under a moderate pressure, returning from a state of disintegration to one of solidity; which qualities of friability and regelation have been shown by the experiments of Professor Tyndall to be sufficient (the requisite force "a tergo" being supposed) to account for its crushing its way through contractions in its channel, and reconstructing itself at the bottom of ice-cataracts. Now such a glacier, if it be supposed penetrable to external heat as lead is, could not but descend as lead does. In its descent portions of it would be thrust forward and compressed, and others would be dragged behind and crevassed. The melting of the lower part of such a glacier would favour its descent as compared with the lead whose mass remains unchanged. All these conditions might, however, be influenced by variations in the form of its channel and the inclination of its bed. Its motion would be like that of a snail clinging, but descending.

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* See the experiments of Schumacher at Pultowa, as detailed in the paper of W. Struve, "Sur la dilatation de la Glace," Mém. de l'Académie de St. Pétersbourg, ser. 6. tom. iv. 1848.

The whole question, however, depends upon the penetrability of the glacier to external heat. On this point we have the high authority of Professor Forbes, founded on three series of observations on the motions of the Mer de Glace and the Glaciers des Bossons and des Bois. Of these observations, made in the summers of 1842 and 1844, he has recorded the results in his 'Travels in Savoy' (2nd ed. p. 141), and in his recent work entitled 'On the Theory of Glaciers' (p. 131); and he has compared them with the mean daily temperatures of the air as recorded at Geneva and the Great St. Bernard. He has, moreover, represented the relation between the average daily motions of these glaciers, and the average daily temperatures of the air at the corresponding periods by means of diagrams, which it is impossible to look at, however cursorily, without being struck with the fact (not to be better expressed than in the words of Mr. Forbes himself), that they establish a "close relation between the mean temperature of any portion of the year, and the velocity of the glacier corresponding to it*." Moreover, it is not only on the surface of the glacier that this relation may be considered to have been observed. The glacier moves with different velocities at different depths; but all are related to its surface motion, so that the influence of variations of temperature, if felt on its surface, must penetrate throughout its depth. Being dilatable as lead is (but in a higher degree), and being thus shown to be sensible to variations of temperature throughout its mass, it cannot but descend as lead under the like circumstances does. Every variation of temperature, however slight, cannot but produce a corresponding descent, and such small variations, often enough repeated, might produce a descent, however great, even although at each change the glacier returned to the same temperature. The oscillation of the heat backwards and forwards is all that is required. For the purpose of this argument, the fact that a relation exists between the motion of a glacier and the external temperature is all that is required. It is not necessary to enter on a discussion of the causes out of which that relation arises.

On Meteorological Observations for 1859, *made at Huggate, Yorkshire, East Riding. By the* Rev. T. RANKIN.

This communication was in continuation of similar observations and general remarks furnished, by the same author, to the Association for upwards of twenty years.

On Thermo-barometers, compared with Barometers at great Heights.

By M. R. de SCHLAGINTWEIT.

M. Robert de Schlagintweit communicated some of the results which he had deduced from comparisons of the boiling-point with direct barometric readings. These observations, taken by his brothers and himself during their journeys in India, the Himalaya, &c., at various heights and different periods, were chiefly made to test by direct experiments the correctness of the tables of the boiling-point of water corresponding to barometric pressure, of which the latest and the most detailed ones are those of Magnus, Regnault, and Moritz.

Direct observations had been previously made in India, particularly by Colonel Sykes; in America, Mr. Wisse made such experiments up to 14,000 feet; in High Asia, Messrs. de Schlagintweit had occasion to carry on such observations up to heights exceeding 18,600 feet.

A resulting Table of comparison was presented, an examination of which showed

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[*] Forbes, Theory of Glaciers, p. 130.

that, for all practical purposes, the tables quoted above are quite accurate enough, though for great heights, they contain an error; the correction to be applied is small, and additive. The instruments with which Messrs. de Schlagintweit made their observations, were expressly made for the purpose; they ranged from 100° Cels. to 78° Cels., but had a length of 1 foot 9 inches, so that it was possible to divide each degree into fifty parts directly. M. de Schlagintweit drew attention to the accuracy of the results obtainable by these delicate thermo-barometers, which, as far as his experience goes, he considered to be quite comparable to the barometer, if used with *all* the necessary precautions, though for daily variations the barometer is preferable on account of the greater facility of reading. The circumstance that the thermo-barometer is much less liable to get out of order, makes it a most valuable instrument for travellers.

Messrs. de Schlagintweit's Comparison of Boiling-points.

Name of the place of observation.	Year and Date.	Thermo-barometer readings, C. degrees.	Simultaneous barometric readings.		Correction in C. degrees.
			Millimetres.	Millims. reduced to boiling-point, C. degrees.	
Group I.—100° to 96°: Correction −0°·09 of the Thermo-barometer*.					
Súni	1856, April 7	97°·99	704·6	97°·90	−0°·09
Keterbál	1855, Sept. 12	96·84	675·7	96·75	−0·09
Petólia '	1855, Sept. 12	96·73	673·5	96·66	−0·07
Okimath	1855, Sept. 15	95·85	652·9	95·81	−0·04
Okimath	1855, Sept. 16	95·85	651·7	95·76	−0·09
Group II.—95·99 to 94: Correction −0°·10 of the Thermo-barometer.					
Thósimath	1855, Sept. 9	94·06	610·4	93·99	−0·07
Pandukéser	1855, Sept. 8	93·99	608·2	93·89	−0·10
Thósimath	1855, Sept. 9	93·98	607·0	93·84	−0·14
Gaurikúnd	1855, Sept. 24	93·78	603·3	93·67	−0·11
Gaurikúnd	1855, Sept. 23	93·73	601·2	93·58	−0·15
Gaurikúnd	1855, Sept. 19	93·64	601·0	93·57	−0·07
Giunáli	1855, Sept. 29	93·13	587·3	92·95	−0·18
Símla	1856, April 12	93·00	585·7	92·88	−0·12
Tríchŭgi Naráin	1855, Sept. 24	92·96	585·2	92·86	−0·10
Group III.—93·99 to 92: Correction −0°·11 of the Thermo-barometer.					
Minasáura	1855, Sept. 28	90·76	537·9	90·62	−0·14
Bádrinath	1855, Sept. 7	90·20	527·5	90·10	−0·10
Bádrinath	1855, Sept. 5	90·18	526·6	90·06	−0·12
Bádrinath	1855, Sept. 6	90·12	525·6	90·01	−0·11
Mángu Pass	1855, Sept. 26	89·87	520·0	89·73	−0·14
Mána	1855, Aug. 28	89·85	519·1	89·69	−0·16
Group IV.—91·99 to 90: Correction −0°·12 of the Thermo-barometer.					
Kídarnath	1855, Sept. 20	88·68	498·1	68·61	−0·07
Kídarnath	1855, Sept. 20	88·67	497·8	88·59	−0·08
Shemkárik	1855, June 11	87·66	477·2	87·49	−0·17
Laptél	1855, June 14	86·70	459·6	86·53	−0·17
Loànka	1855, July 7	84·72	425·9	84·58	−0·14
Group V.—89·99 to 81: Correction −0°·13 of the Thermo-barometer.					
Jbi Gámin	1856, Aug. 16	83·02	397·7	82·85	−0·17
Jánti Pass	1855, July 10	82·20	385·5	82·07	−0·13
Jánti Pass	1855, July 9	82·16	385·5	82·07	−0·09
Jbi Gámin Pass	1855, Aug. 18	81·56	375·6	81·42	−0·14

* The corrections of the thermo-barometer, given at the different groups, are values obtained by fundamental determinations. These determinations will be given in detail in vol. ii. of Messrs. de Schlagintweit's 'India and High Asia,' 1861.

On Practical Experience of the Law of Storms in each Quarter of the Globe. *By* Captain W. PARKER SNOW.

From practical experience in several parts of the globe, Captain Snow confirmed the soundness of the theory of the Law of Storms brought forward by Admiral FitzRoy. In one place, well known to the Admiral, viz. the tempestuous seas about Cape Horn, he, Capt. Snow, had cruised for two years without the smallest damage to his vessel, and this owing to the attention he ever paid to those laws of nature in connexion with wind movements.

On another occasion, off the coast of Australia, he preserved his little ship, by similar attention, in a terrific gale, when at the same time several other vessels were wrecked. He well remembered how his chief officer derided the idea of any storm theory being true, and, when referred to Reid and other stormists, said he had never heard of them, and did not believe in what they might say. But that same night the mate was convinced when the gale took the turn predicted by the captain.

One more occasion Capt. Snow would refer to. He was coming home as passenger in a sailing ship; it was in the end of 1856. Within a few days' sail from England a cyclone came down upon them. Clearly it was passing ahead, and Capt. Snow advised his brother captain to adopt those measures which prudence then suggested, and allow the centre to go by. After some argument this was done; but, to convince the master of the ship, Capt. Snow said that the correctness of his view of the case then, would be proved by the direction of the wind at that time in the South of England, which should be opposite to what they had it. Four days afterwards they took a pilot, and ascertained it to have been exactly so.

NOTE.—The above is merely the substance of remarks made when Admiral FitzRoy read his paper. They form the outline of what was read on a following day, by Captain Snow, when he entered upon details.

Results of an Investigation into the Phenomena of English Thunder-storms during the years 1857–59. *By* G. J. SYMONS.

This paper contained an analysis of 1889 observations made in various parts of England during the three years ending December 31st, 1859.

The average number of days on which thunder-storms occurred at one or more stations was 121, the number of days in each month being—

January	3	April	12	July	13	October	10
February	2	May	18	August	14	November	6
March	6	June	20	September	12	December	5

The effect of thunder-storms on the various meteorological instruments was examined and described, special attention being drawn to those sudden oscillations of the barometer which occur during the height of a storm, and which have been found by Mr. Eaton, of Little Bridy, to be contemporaneous with tidal disturbances. The shape, colour, and disruptive force of lightning were also treated in detail, the frequency with which it assumes a globular form being proved by the number of cases in which it is so described: the determination of colour was not perfectly satisfactory; the returns taken generally show that forked lightning is usually blue, sheet lightning being, on the contrary, white. Mr Symons, however, supposes that the colour may vary with the distance of the discharge from the observer, with the density of the air through which it passes, and with the existence or non-existence of other sources of illumination; but the subject is quite open to investigation: the disruptive force was shown to be often equal to a dead weight of 500 tons.

The advantage of employing the gutters and rain-water pipes of private houses as lightning conductors, by establishing perfect communication with the earth, and at the same time carrying a short rod from the gutter up the side of the chimneys, was discussed; the author's opinion being that, although far from a perfect arrangement, it would determine the discharge to the outside of the house rather than inside, its most frequent course; and from its trifling cost it seems more adapted for general use than the expensive forms hitherto employed.

Notes on Atmospheric Electricity.

By Professor WILLIAM THOMSON, *LL.D., F.R.S.*

Two water-dropping collectors for atmospheric electricity were prepared, and placed, one at a window of the Natural Philosophy Lecture-room, and the other at a window of the College Tower of the University of Glasgow. A divided ring-electrometer was used at the last-mentioned station; an electrometer adapted for absolute measurement, nearly in the form now constructed as an ordinary house electrometer, was used in the lecture-room. Four students of the Natural Philosophy Class, Messrs. Lorimer, Lyon, M'Kerrow, and Wilson, after having persevered in preliminary experiments and arrangements, from the month of November, devoted themselves with much ardour and constancy during February, March, and April to the work of observation. During periods of observation, at various times of day, early and late, measurements were completed and recorded every quarter-minute or every half-minute; the continual variations of the phenomenon rendering solitary observations almost nugatory. During several hours each day simultaneous observation was carried on on this plan at the two stations. A comparison of the results manifested often great discordance, and never complete agreement. It was thus ascertained that electrification of the air, if not of solid particles in the air (which have no claim to exclusive consideration in this respect), between the two stations and round them, at distances from them not very great in comparison with their mutual distance, was largely operative in the observed phenomena. It was generally found that after the indications had been negative for some time at both stations, the transition to positive took place earlier by several minutes at the tower station (upper) than at the lecture-room (lower). Sometimes during several minutes, preceded and followed by positive indications, there were negative indications at the lower, while there were only positive at the upper. In these cases the circumambient air must have contained negative (or resinous) electricity. A horizontal stratum of air several hundred feet thick overhead, if containing as much positive electricity per cubic foot as there must have been of negative per cubic foot of the air about the College buildings on those occasions, would produce electrical manifestations at the earth's surface similar in character and amount to those ordinarily observed during fair weather.

Beccaria has remarked on the rare occurrence of negative atmospheric indications during fair weather, of which he can only record six during a period of fifteen years of very persevering observation by himself and the Prior Ceca. On some, if not all of those occasions, there was a squally and variable wind, changing about rapidly between N.E. and N.W. On several days of unbroken fair weather in April and May of the present year the atmospheric indication was negative during short periods, and on each occasion there was a sudden change of wind, generally from N.E. to N.W., W., or S.W. For instance, on the 3rd of May, after a warm, sunny, and very dry day, with a gentle N.E. breeze and slight easterly haze in the air, I found about 8·30 P.M. the expected positive atmospheric indication. After dark (nearly an hour later) it was so calm that I was able to carry an unprotected candle into the open air and make an observation with my portable electrometer. To my surprise I found a somewhat strong negative indication, which I observed for several minutes. Although there was no sensible wind in the locality where I stood*, I perceived by the line of smoke from a high chimney at some distance that there was a decided breeze from W. or S.W. A little later a gentle S.W. wind set in all round, and with the aid of a lantern I found strong positive indications, which continued as long as I observed. During all this time the sky was cloudy, or nearly so. That reversed electric indications should often be observed about the time of a change of wind, may be explained with a considerable degree of probability, thus:—

The lower air up to some height above the earth must in general be more or less electrified with the same kind of electricity as that of the earth's surface, since this reaches a high degree of intensity on every tree-top and vegetable fibre, and must therefore cause always more or less of the phenomenon, which becomes conspicuous as the "light of Castor and Pollux," known to the ancients, or the "fire of St. Elmo" described by modern sailors in the Mediterranean, and which consists of a flow of electricity of the kind possessed by the earth into the air. Hence, in fair weather the lower air must be negative, although the atmospheric potential, even close to the earth's surface, is still generally positive. But if a considerable area of this lower stratum is carried upwards into a column over any locality by wind blowing inwards from different directions, its effect may for a time predominate, and give rise to a negative potential in the air and a positive electrification of the earth's surface.

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* About six miles south of Glasgow

If this explanation is correct, a whirlwind (such as is often experienced on a small scale in hot weather) must diminish, and may reverse the ordinary positive indication.

Since the beginning of the present month I have had two or three opportunities of observing electrical indications, with my portable electrometer, during day thunderstorms. I commenced the observation on each occasion after having heard thunder, and I perceived frequent impulses on the needle which caused it to vibrate, indicating sudden changes of electric potential at the place where I stood. I could connect the larger of these impulses with thunder heard some time later, with about the same degree of certainty as the brighter flashes of lightning during a thunder-storm by night are usually recognized as distinctly connected with distinct peals of thunder. By counting time I estimated the distance of the discharge, not nearer on any occasion than about four or five miles. There were besides many smaller impulses, and most frequently I observed several of these between one of the larger and the thunder with which I connected it. The frequency of these smaller disturbances, which sometimes kept the needle in a constant state of flickering, often prevented me from identifying the thunder in connexion with any particular one of the impulses I had observed. They demonstrated countless discharges, smaller or more distant than those that gave rise to audible thunder. On none of these occasions have I seen any lightning. The absolute potential at the position of the burning match was sometimes positive and sometimes negative; and the sudden change demonstrated by the impulses on the needle were, so far as I could judge, as often augmentations of positive or diminutions of negative, as diminutions of positive or augmentations of negative. This afternoon, for instance (Thursday, June 28), I heard several peals of thunder, and I found the usual abrupt changes indicated by the electrometer. For several minutes the absolute potential was small positive with two or three abrupt changes to somewhat strong positive, falling back to weak positive, and gathering again to a discharge. This was precisely what the same instrument would have shown anywhere within a few yards of an electrical machine turned slowly so as to cause a slow succession of sparks from its prime conductor to a conductor connected with the earth.

I have repeatedly observed the electric potential in the neighbourhood of a locomotive engine, at work on a railway, sometimes by holding the portable electrometer out of a window of one of the carriages of a train, sometimes by using it while standing on the engine itself, and sometimes while standing on the ground beside the line. I have thus obtained consistent results, to the effect that the steam from the funnel was *always negative*, and the steam from the safety-valve always positive. I have observed *extremely strong* effects of each class from carriages even far removed from the engine. I have found strong negative indications in the air after an engine had disappeared round a curve, and its cloud of steam had dissolved out of sight.

In almost every part of a large manufactory, with steam-pipes passing through them for various heating purposes, I have found decided indications of positive electricity. In most of these localities there was some slight escape of high pressure steam, which appeared to be the origin of the positive indications.

These phenomena seem in accordance with Faraday's observations on the electricity of steam, which showed high pressure steam escaping into the air to be in general positive, but that it was negative when it carried globules of oil along with it.

Note on the Dispersion of the Planes of Polarization of the Coloured Rays produced by the Action of Magnetism. *By* M. VERDET, *Paris.*

The researches in which I have been for some years engaged upon the magnetic relations of the plane of polarization, discovered as we all know by Mr. Faraday, have naturally led me to examine how these relations vary with the *nature*, or, using theoretical language, with the length of the undulation, of the light. The experimental method which I have employed is the general method introduced into science by MM. Fizeau and Foucault, which consists in decomposing the white light after it has traversed the apparatus in which it has suffered a certain modification; and in examining how this modification varies from one extremity to the other of the spectrum thus obtained, selecting especially, for the numerical measure of the relative effect, the seven principal rays which Fraunhofer has defined, and the length of those undulations he has determined. As the exact determination of the position of a plane of polarization requires that the light shall have a certain intensity, I have been obliged to confine myself to measuring the relations of beams which correspond with five rays, C, D, E, F and G.

As in my previous researches, in order to operate upon certain bodies well defined and easily reproduced, I have always experimented upon liquids, contained in tubes closed at their extremities by transparent plates; placing these tubes in the interior of a strong electro-magnetic coil, and so arranged that their two ends shall sufficiently pass the edges of the coil, to obviate the necessity of taking into account the action which the transparent plates themselves might exercise on polarized light. But under these conditions the employment of a powerful current was rendered absolutely necessary by the feebleness of the phenomena; and the nature of the experiments requiring that each liquid should remain for a long time under observation, an elevation of temperature was produced which easily reached 50° or 60° Centigrade, and which produced a contraction of the rotations observed, which it was very difficult to correct.

The only way of avoiding this source of error, was to place the tube containing the liquid in an annular collar continually traversed by a stream of cold water within the electro-magnetic coil,—a considerable complication to the apparatus.

The coil which I employed was not less than 45 centimetres in length, 15 centimetres in internal, and 30 centimetres in external diameter. It contained more than 80 kilogrammes of copper wire 2·25 millimetres in diameter, and was set in action by a Bunsen's battery of twenty or thirty elements.

I have not yet quite finished my experiments, but I am now in a position to establish one result, which does not appear to me to be unworthy of being communicated to the Association. M. Wiedemann, in a note published in 1851, believed that he might deduce from a small series of experiments, that if one submitted to the action of magnetism a substance capable of itself of turning the plane of polarization, such as the spirit of turpentine or essential oil of lemon, the rotation proper to the substance and the magnetic rotation were proportional to one another through all the colours of the spectrum. In order to submit to a decisive proof this law, which would be, were it true, of immense theoretical importance, I have just examined an extreme case, that of tartaric acid. We know that solutions of this acid induce in the planes of polarization rotations which do not increase from the red to the violet, as in ordinary cases, but which present in the interior of the spectrum a maximum whose exact position varies with the strength of the solution. Were the relations admitted by M. Wiedemann correct, the magnetic rotations of tartaric acid should present the same anomaly. My experiments have, however, proved, on the contrary, that the magnetic rotations in different solutions of this acid always increase from the red to the violet. There is no essential relation between the two orders of phenomena, as there is no analogy between their causes.

On the other hand, my experiments show how the two phenomena may have appeared in some cases proportional. They show, in fact, that in all cases the magnetic rotations of the plane of polarization increase very rapidly from the red to the violet, but that the product of the rotations by the square of the length of the undulations, increase very slowly between the same limits; and one recognizes in this announcement, that which experiment has long ago demonstrated in most of the natural rotatory powers.

Results of Self-registering Hygrometers. *By* E. VIVIAN, *M.A., Torquay.*

Mr. Vivian reported to this Section a series of observations made with his new self-registering hygrometers, which were first exhibited before the Association at its Cheltenham meeting. One is a combination of the ordinary wet and dry bulb and the differential thermometers, registering the *maximum* and *minimum*, or range during any period; the other, by the continuous precipitation of the vapour from alcohol, records the *mean* amount of difference between the wet and dry bulbs. The curves laid down from these instruments varied very greatly from that of the ordinary observations at 9 A.M. The instruments are very simple, and not capable of derangement. Curves were also exhibited showing the character of the climate of Torquay during a long series of years, from observations periodically communicated to the Registrar-General. The comparison with the average of other places in England showed the climate of South Devon to be very much more equable, both in regard to temperature and humidity. The summers are as much cooler as the winters are more mild. The fall of rain is rather greater, but the number of wet days is less. Other curves exhibited the degree of confidence to be placed in the barometer in prognosticating changes in the weather, and the influence of the moon, which was only discoverable in the more disturbed state of the atmosphere at the times of the spring tides.

Results of Ten Years' Meteorological Observations at Stonyhurst.
By the Rev. A. WELD.

Stonyhurst College is situated in the county of Lancashire, in lat. 53° 50′ 40″ N., and long. 9° 52′ W. It stands at an elevation of 380 feet in the S.E. vicinity of Longridge Fell, which rises upon elevated broken undulations from the bed of the Ribble to 1140 feet. In the centre of the garden, which commands a wide extent of country, was chosen the site for the observatory, having on all sides generally a free and distant horizon. The observatory contains a 5-foot equatorial, a meridian circle 2½ feet diameter, a transit instrument, two transit clocks, and a considerable meteorological apparatus. The report opens with an historical sketch of the origin of the Meteorological Observations in 1847. The instruments have been compared with standards by Mr. Glaisher, of the Royal Observatory, Greenwich. The report extends over ten years, from the beginning of 1848 to the end of 1857. The chief instruments recorded have been the barometer; the dry and wet bulb; the highest and lowest readings of the thermometer in the shade; the highest of a thermometer with a blackened bulb exposed to the sun's rays, and the lowest of a thermometer exposed upon grass; the direction and estimated force of the wind, and the amount of cloud at the time of each observation; the daily and monthly fall of rain and snow; amount of evaporation from an exposed surface of water; the general circumstances observed to attend Aurora Borealis and thunder-storms; and a general description of the state of the weather and appearance of the sky. The observations were recorded at 9 A.M., 1 P.M., 3 P.M., and 9 P.M., local time, which have been made, almost without exception, throughout. The report describes at length the methods used in recording and reducing the observations. Then follow the tables and very carefully executed curves and diagrams, with explanatory notes interspersed.

GENERAL PHYSICS.

Physics as a Branch of the Science of Motion.
By J. S. STUART GLENNIE, *M.A.*

In order that the great aim of modern science may be accomplished, and mechanical principles be rigorously applied to physical and chemical phenomena, it seems clear that physical and chemical forces must be conceived in the same way as mechanical forces. Therefore, as the general condition of the development of a mechanical force, and, consequently, of a mechanical motion, is a difference of pressures, and as a mechanical motion is in the direction of least pressure, a physical or chemical force must be similarly conceived as a difference of pressures, and attractions and affinities explained as motions in the direction of least resistance: and as the cause of an ordinary mechanical motion is no supernatural or unrelated entity or agent, but simply the condition or relation of difference among a set of mutual pressures, so the causes of physical and chemical motions must be conceived, not as agents, but as relations. But as (though an absolute force is inconceivable) we may speak of a moving body as a mechanical force because it cannot come into contact, be brought into relation with another body without there being thus a difference of the previously existing polar pressures on that body, and hence a motion or change of motion; so we may speak of heat, electricity, &c. as forces, because bodies in such states of molecular motion or tension cause a motion of other bodies, or of their molecules. And these forces are thus conceived, not as absolutely existing agents acting on matter, but as conditions of matter.

It is evident that this idea of force, by which all particular forces become one (by being referred to the same general conception of a difference of pressure), postulates a plenum. But this will probably be now generally granted. If, then, there is a plenum, we may conceive the influence which every part of matter exerts on every other, as acting not "at a distance," but through other intermediate matter, forming lines of pressure. Hence we may conceive a body or molecule as a centre of pressure, and see whether, retaining the usual mechanical conception of "pressure" as "a balanced force," or "virtual momentum," such influence, or, more definitely, physical and chemical phenomena, become mechanically explicable.

A molecule, therefore, or body, an aggregate of molecules, is conceived as a centre of lines of pressure; the lengths and curves of these lines are determined by the relative pressure of the lines they meet; and lines from greater, are made up of similar lines from lesser molecules, and so on *ad infinitum*. In speaking of a molecule or body as such a centre of pressure, we may, for convenience sake, call it an atom. In chemistry, the term equivalent will be used exclusively, and not as more or less synonymous with atom, which I have thus ventured to appropriate for a new conception.

Atoms, or mutually determining centres of lines of pressure, may also be defined and mathematically considered as mutually determining elastic systems with centres of resistance.

But these fundamental conceptions of centres of lines of pressure, or centrally resisting elastic systems, are not hypotheses, but convenient forms of the general conception of the parts of matter as mutually repelling.

If, in a system of such atoms, the centres, whether molecules or suns, are all of equal mass, and at equal distances, the mutual repulsions of their lines will be equal in all directions; there will be no difference of pressure, no moving force will be developed, and the conditions of equilibrium are satisfied. But it was shown that if there are in such a system differences in the masses of the resisting centres, or in their relative positions, the law of universal attraction, or approach of these centres, whether, in any particular case, equal or unequal, would follow as a mechanical consequence of the deflection of the mutually opposing lines.

But such centres may differ not only in mass, but in tension. Tension is conceived as a state of unstable equilibrium, in which a (molecular) atomic centre, having been moved towards the next atom in any plane, rests in a position in which the pressure of its lines is increased in that direction, and correspondingly, of course, diminished in the opposite. Such is the general mechanical conception of polarity proposed in this theory.

The phenomena caused by bodies in a state of static electricity are deduced from the conception of outward or inward tension in a closed curve.

In dynamically electrified bodies the tension is conceived as longitudinal, and the poles as the ends towards and from which the molecules have been moved. A magnet is conceived as a body in which the molecules are in a permanent state of transverse tension; and hence, evidently, as in Ampère's theory, the analogy (except as to power on iron core) between a helix and a magnet.

Induction is the necessary mechanical effect on adjacent bodies of electricity or magnetism as above conceived. The character of that effect depends on the relative conditions of the tension of the acting body, and of the mechanical resistance due to the molecular motion or aggregation of the bodies acted on.

The various motions in the presence of electric or magnetic bodies are explicable as differential effects of (electric or magnetic) conduction.

It is proposed to apply this general theory to the undulatory theory of light and heat, with the hope that the difficulties therein at present encountered may be hereby overcome.

As to chemistry, it may be briefly noted that its phenomena seem capable of being brought within the science of motion by deductions from the general conceptions of a body as a system of moving molecules (specific heat), which, the motion at every point being equal in intensity, is in a state of dynamic equilibrium; and of the formation of compounds, as the formation of new states of dynamic equilibrium.

A General Law of Rotation applied to the Planets.

By J. S. STUART GLENNIE, *M.A.*

The author directed attention to a table of elements which seemed to point to a general law for the angular velocity of rotation of the planets; though, of the many formulæ calculated, none had as yet given perfect accuracy.

But these tables gave a new law connecting the angular velocities of revolution with the distances.

He referred the nullity of effect on the planets of the resisting medium which shortens the periods of Encke's comet to a neutralization deduced from a hydrodynamical theorem.

SOUND.

On the Velocity of the Sound of Thunder.

By the Rev. S. EARNSHAW, *M.A.*

The object of this paper was stated by its author to be, to solicit the attention of observers to certain phenomena which seem to indicate that the velocity of the sound of thunder is sometimes much greater than that of ordinary sound. He had himself noticed a case where the sound followed close upon the flash of lightning, though judging from the distance of the point struck (more than a mile) from him, the interval between the flash and the sound should have been upwards of five seconds. He stated also that Professor Montigny of Antwerp had communicated to him accounts of similar instances noticed by himself and M. Raucoux, curé of Temploux. One in particular was very remarkable. On a certain night last autumn, Professor Montigny observed the lightning strike a farm at such a distance from him, that, according to the received velocity of sound, more than fifteen seconds ought to have elapsed before he heard the report, whereas it reached him in two seconds. This was confirmed to him the next day by the curé of Temploux, who being at nearly the same distance from the farm, heard the crack of the thunder in what he judged to be certainly not more than two seconds from the descent of the electric fluid. The difference in this case is so great between theory and observation, that errors of estimation of the time cannot possibly account for it. The two observers were more than 4000 mètres apart. The author stated, that although there were in these instances such discrepancy between them and the received theory, he had communicated investigations to the 'Philosophical Magazine' with which they were in perfect agreement. But, nevertheless, he hoped that some of the members of the Association would turn their attention to these phenomena, in order that it might be definitely settled, whether his theoretical deductions are, or are not, supported and confirmed by undoubted facts.

On the Triplicity of Sound. By the Rev. S. EARNSHAW, *M.A.*

The fundamental idea of this paper is the hypothesis of finite intervals. Setting out from this, the author shows that the most simple elements of wave-motion are defined by the equation $\frac{d^2x}{dt^2}=\pm k^2x$, x being the displacement of an aërial particle at any time t. If the radius of molecular action extend over a large number of particles, the method pursued by the author gives the velocity of ordinary sound 1130 feet. He also shows that the velocity of a thunder-clap must of necessity be greater than that of ordinary sounds. There are two essentially distinct types of wave-motion, corresponding to the two signs with which k^2 is affected in the above equation; the upper sign belongs to the thunder type, and the lower to ordinary musical sounds: and it is shown that for a *given value of* k *there are three different velocities of wave transmission*, viz. one corresponding to the upper sign, and two to the lower sign. This is what the author means by the triplicity of sound. The papers on this subject will be found printed at length in the 'Philosophical Magazine' for June, July, and September.

INSTRUMENTS.

Description of an Instrument for Measuring Actual Distances.

By PATRICK ADIE.

The telemeter consists of two telescopes so arranged in two concentric tubes, that the rays formed by two object-glasses, at or near the extremities of the tubes, are by means of reflectors brought together into one eyepiece in the middle of the tubes; thus both telescopes are simultaneously pointed at the same object, one being moveable, and their relative angle taken from a scale and vernier, and this by reference to a table on the instrument gives the distance of the object looked at. The author has obtained measures to 5 yards in 500, and 20 in 1000 with a base of only 18 inches. The length of the arm and power of the telescopes being equal to such minute accuracy, this promises to supply the link wanting to make the long range in gunnery useful. Its power is such, that with the 18-inch base, the one described, we can read to 5 yards in 500, or 20 in 1000, and it may be used up to 4 or 5 miles with effect.

Description of a New Reflecting Instrument for Angular Measurement.

By PATRICK ADIE.

The instrument is a sextant or circle which the author proposed to name the binocular reflector. It consists of two telescopes, also so arranged as to work with one eyepiece, one telescope being directed to each of the objects whose angular distance is sought; one of these is fixed below the limb, the other above it; and the rays are passed from the lower into the upper, by means of a reflector sending them at right angles through the centre of the instrument, which is hollow; these rays entering the upper telescope, are by means of a second reflector passed along with those of the other half which is open into the eyepiece. The point of this instrument is, that it gives the whole instead of half degrees as in Hadley's principle, thus reducing the size of the instrument one-half, and the cost nearly in like degree; it will also be much less subject to disarrangement, and can measure any angle up to 180°.

On a Pile with Sulphate of Lead. *By* M. E. BECQUEREL.

The pile of M. Edmond Becquerel is composed of an exterior receiver of zinc of an annular shape, and of a cylinder composed as follows. A cylinder of lead of 29 centimetres (9¼ inches) long and about half a centimetre ($\frac{2}{10}$ths of an inch) diameter, is placed in the inside of a mould 13 centimetres (4·6 inches) in height, and 9 centimetres is filled (2¼ inches) in diameter, with a paste of sulphate of lead pulverized, and 400 grammes water saturated with marine salt at 25° of the areometer, (being 129 to 139 cubic centimetres. The mixture of these should be made very quickly. After the sulphate of lead has acquired a sufficient consistence, we remove it from the mould, and we cover it round with a bed of plaster of half a centimetre in thickness. This pile is charged with water rendered saline with common (sea) salt about ¼th saturated. Its electromotive force is equal to the half of that of sulphate of copper, and its resistance to conduction is equivalent to 100 metres of red copper wire of a millimetre diameter. It has the advantage of being very simple, and of not requiring anything to keep it in action; it is put into action by a single liquid, and does not need a porous vessel. It possesses much constancy, and does not cease to act until the sulphate of lead is entirely reduced to the metallic state. M. Becquerel had one in action composed of ten pairs, of which the circuit remained completely closed for three months.

On an Atmotic Ship. By the Hon. W. Bland, *New South Wales.*

The proposal in this case was to employ a light keel and ship-formed body buoyed up by an elongated balloon, and two heavy weights guided by a rope slung from stem to stern, to alter the centre of gravity of the machine and direct its motion upwards or downwards at pleasure. To cause it to move onwards in any assigned direction, large but light and strong vanes were to be driven round, acting like the screw propeller of a ship.

On an Improved Instrument for describing Spirals, invented by Henry Johnson. *By the* Rev. J. Booth, *LL.D., F.R.S.*

Mr. Johnson's instrument, which, looking to its practical use, he calls a volutor, admits of several varieties, and may be briefly described as follows:—The form which most clearly exemplifies the principle consists of a vertical axis resting on a horizontal plane, and retained on it by a metal point to prevent slipping or lateral motion. To this upright axis is attached one extremity of the horizontal arm or bar. The vertical axis passes through the extremity of the horizontal arm, or a block attached to the end of it, in such a way that the horizontal arm may revolve freely round the vertical axis. The remote extremity of the horizontal bar is furnished with a drum or pulley, over which a band or chain passes; one end of this band is affixed to the centre upon a level with the pulley, and the other end of the chain or band, after passing over the pulley at the outer end of the horizontal rod, returns and is attached to a slide which carries a pencil or marking instrument. The horizontal bar is made to revolve, either by the hand directly applied to it, or by a string wound round a drum attached to the block revolving on the vertical axis.

The chain or band is thus wound round the upright axis, while each succeeding coil encloses the preceding one, and is supported by a small plane projecting from the centre. The slide is drawn from the centre towards the drum at the other end of the horizontal arm, and thus the curve is traced by the pencil or other point, progressively increasing its radius vector as the slide recedes from the axis. The addition of small tubes to slide down, when required, to the junction, with an opening for the chain or band, will afford the means of varying the size of the axis, and consequently the interval between the successive spirals of the curve. The intervals between the spirals are determined by the size of the axis, and the thickness of the band coiled round it. When each coil round the cylindrical axis rises above the preceding one, without enclosing it, the spiral of Archimedes is described, as the radius vector is increased each revolution by the circumference of the axis, neglecting the inclination of the cord.

A cone may be conveniently used as a centre, and the band wound round it in lieu of being wound in a flat coil; and the size of the centre may be enlarged, by winding the band one or more times round the cone before tracing the curve.

A number of pulleys are affixed to the slide and the block on the axis, and the curve may be modified by passing the band over one or more of them.

As the vertical axis of the volutor, and the slide on the horizontal bar to which motion is communicated, are connected by a cord or chain passing over a system of pulleys, the length of cord which wraps round the vertical cylinder becomes $2n$ times the radius of the spiral, n being the number of pulleys attached to the slide which travels on the horizontal arm. Hence, by increasing n, we may diminish the magnitude of the spirals described by the volutor *.

When, instead of the vertical cylinder round the axis, a grooved cone is substituted, the width of the whorls increases with each revolution of the radius vector of the spiral; and by substituting in succession a series of cones in the vertical axis, each of a different pitch, we may obtain spirals where successive whorls shall widen out in any given ratio.

Recent improvements in the volutor, as shown in the annexed drawing, include arrangements for the vertical position of the pencil, as also for attaching the band to the base of the cone when required, and for applying the set of pulleys to either end of the horizontal bar.

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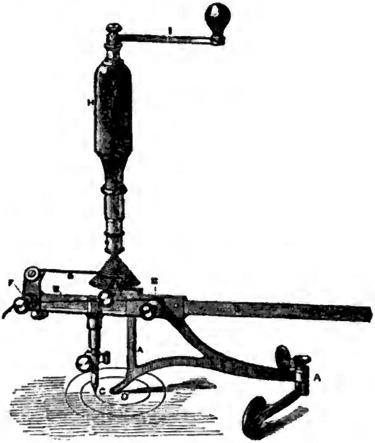
* In fact, the cord wound round the axis, and the end of the slide which carries the tracing point, are as power and weight in a system of mechanical pulleys.

In addition to the spirals that are traced, when the band is wound first round the apex of the cone *descending* to the base, by the pencil receding from the centre, on the principle described; spirals may also be traced by the pencil approaching the centre from the extremity of the radius vector, when the pulleys are attached to the pencil end of the horizontal bar, and the band is wound round the grooved cone *ascending* from the base.



A A stand, with wheels moveable round the central point O.
B Horizontal bar, passing through the horizontal tube D on stand.
C Tracing pencil, pressed down by vertical spiral spring.
D Horizontal tube on stand.
E Set of pulleys on stand.
F Set of pulleys screwed on to the end of the horizontal bar.
G Band wound about the grooved cone at the centre, and passing over pulleys at F and E.
H Handle attached to grooved cone, and held stationary with one hand; while the stand carrying horizontal bar, &c., is moved by means of a winch handle attached to the top of a steel axis rising through the cone and handle.
I The winch handle.

On the Means of increasing the Angle of Binocular Instruments, in order to obtain a Stereoscopic Effect in proportion to their Magnifying Power.

By A. CLAUDET, *F.R.S.*

In a paper on the stereoscope, which Mr. Claudet read before the Society of Arts in the year 1852, alluding to the reduction of the stereoscopic effect produced by opera glasses on account of their magnifying power, he stated that, in order to redress that defect, it would be necessary to increase proportionately the angle of the two perspectives. This he proposed to do by adapting to the object-glasses two sets of reflecting prisms, which by a greater separation given to the two lines of perspectives, would reflect on the optic axes images taken at a greater angle than the angle of natural vision. Such was the instrument that Mr. Claudet submitted to the British Association, to prove, as he has always endeavoured to demonstrate in various memoirs, that the binocular angle of stereoscopic pictures must be in proportion to the ultimate size of the pictures on the retina,—larger than the natural angle when the images are magnified, and smaller when they are diminished; which, in fact, is nothing more than to give or restore to these images the natural angle at which the objects are seen when we approach them or recede from them. For magnifying or diminishing the size of objects is the same thing as approaching them or receding from them, and in these cases the angles of perspectives cannot be the same. Mr. Claudet showed that, looking at the various rows of persons composing the audience, with the large ends of the opera-glass, all the various rows appeared too close to one another, that there was not between them the distance or space which separates them when we look with the eyes alone; and he showed also that, with the small end, the distance appeared considerably exaggerated. But applying the sets of prisms to the opera-glass in order to increase the angle of the two perspectives, then looking at the audience as before, it appeared that the various rows of persons had between them the natural separation expected for the size of the image or for the reduction of the distance of the objects. By applying the two sets of prisms before the eyes without the opera-glass, it was observed, as was to be expected, that the stereoscopic effect was considerably exaggerated, because the binocular angle was increased without magnifying the objects. But looking with the two sets of prisms alone at distant objects, the exaggeration of perspective did not produce an unpleasant effect. It appeared as if we were looking at a small model of the objects brought near the observer. By the same reason, stereoscopic pictures of distant objects (avoiding to include in them near objects) can advantageously be taken at a larger angle than the natural angle, in order to give them the relief of which they are deprived as much when we look at them with the two eyes, as when we look only with one eye; instead of being a defect, it seems that it is an improvement. In fact, the stereoscope gives us really two eyes to bring out in relief the pictures of distant objects.

On the Principles of the Solar Camera. By A. CLAUDET, *F.R.S.*

The solar camera, invented by Woodward, is one of the most important improvements introduced in the art of photography since its discovery. By its means small negatives may produce pictures magnified to any extent; a portrait taken on a collodion plate not larger than a visiting card can be increased, in the greatest perfection, to the size of nature; views as small as those for the stereoscope can be also considerably enlarged. This is an immense advantage, which is easily understood when we consider how much quicker and in better proportion of perspective small pictures are taken by the camera obscura, while the manipulation is so greatly simplified. There is nothing new in the enlargement of photographic pictures. This has been done long ago simply by attending to the law of conjugate foci; and every photographer has always been enabled, with his common camera, to increase or reduce the size of any image. For the enlargement, it was only necessary to place the original very near the camera, and to increase in proportion the focal distance. But the more the focal distance was increased, the more the intensity of light was reduced; and a still greater loss of light arose from the necessity of diminishing the aperture of the lens, in order to avoid the spherical aberration. Such conditions rendered the operation so long that it became almost an impossibility to produce any satisfactory results when the picture was to be considerably enlarged. For these reasons, it naturally occurred, that if the negative, having its shadows perfectly transparent and its lights quite black, was turned against the strong light of the sun, its image at the focus of the camera would be so intense that the time of exposure would be considerably reduced; so that, in order to employ the light of the sun, and follow easily its position without having to move constantly the whole camera, it was thought advisable to employ a moveable reflecting mirror sending the parallel rays of the sun on a vertical plano-convex lens, condensing those rays on the negative (placed before the object-glass and behind the condenser) somewhere in its luminous cone. Many contrivances for this object were resorted to, but without considering anything else than throwing the strongest light possible on the negative to be copied. The constructors of these solar cameras never thought it very important to consider whether the focus of the condensing lens was better to fall before or behind the front of the object-glass, provided the negative was placed in the luminous cone of the condenser. This want of attention has been the cause which has made the solar camera a very imperfect instrument for copying negatives. The beautiful principle of Woodward's apparatus consists in his having decided the question of the position of the focus of the condenser, and in having placed it exactly on the front lens of the camera obscura. As this principle had not yet been explained when the invention was exhibited before the Photographic Societies of London and Paris, and not even by the inventor himself in the specification of his patent, Mr. Claudet has undertaken, in the interest of the photographic art, to bring the subject before the British Association, and to demonstrate that the solar camera of Woodward has solved the most difficult problem of the optics of photography, and is capable of producing wonderful results. This problem consists in forming the image of the negative to be copied only by the centre of the object-glass reduced to the smallest aperture possible, without losing the least proportion of the light illuminating the negative. The solar camera does not require any diaphragm to reduce the aperture of the lens, because every one of the points of the negative are visible only when they are defined on the image of the sun, and they are so exclusively for the centre of the lens, the only point which sees the sun; while the various points of the negative, which from the marginal zone of the lens are defined against the comparatively obscure parts of the sky surrounding the sun, are, as it were, invisible to that zone; so that the image is produced only by the central rays, and not in the least degree by any other points of the lens, which are subject to spherical aberration. It is, in fact, a lens reduced to an aperture as small as is the image of the sun upon its surface, without the necessity of any diaphragm, and admitting the whole light of the sun after it has been condensed upon the various separate points of the negative. It is evident that from the centre of the lens the whole negative has for background the sun itself, and from the other points of the lens it has for background only the sky surrounding the sun, which fortunately has no effect in the formation of the image. Such is the essential principle of Woodward's solar camera, which did not exist in that instrument when the focus of the condenser was not on the object-glass. This principle is truly marvellous; but it must be observed, that the solar camera, precisely on account of the excellence of this principle, requires the greatest precision in its construction. For its delicate performances, it must be as perfect as an astronomical instrument, which, in fact, it is. The reflecting mirror should be plane, and with parallel surfaces, in order to reflect on the condenser an image of the sun without deformation; and in order to keep the image always on the very centre of the object-glass, the only condition for the exclusion of the oblique rays, the mirror should be capable, by its connexion with a heliostat, of following the movements of the sun. The condenser itself should be achromatic, in order to refract the image of the sun without dispersion, and to define more correctly the lines of the negative; and a no less important condition for losing nothing of the photogenic rays would be, to have the condenser formed with a glass perfectly homogeneous and colourless. With such improvements, the solar camera will become capable of producing results of the greatest beauty; and, without any question, its introduction into the photographer's studio will mark a period of considerable improvement in the art.

On a Reflecting Telescope for Celestial Photography, erecting at Hastings, near New York. By HENRY DRAPER, *M.D.*

In the summer of 1857, after the Dublin meeting of the British Association, a party visited Lord Rosse's telescope at Parsonstown. We were shown the machinery employed in its construction, and, as far as the weather permitted, its performance.

That visit first led me to attempt constructing an instrument which should be specially adapted for celestial photography, for which purpose the reflector possesses such conspicuous advantages over any refractor.

Those who are familiar with photographic operations know well how important it is for the ensuring of uniform success, that the sensitive surfaces should always be placed in similar circumstances as to position, and that position must afford every facility for carrying on the necessary manipulations.

It appeared to me that a modification of a form of mounting, proposed some time ago by Mr. Nasmyth, could be made to answer these requirements perfectly, and that a Newtonian reflector, sustained on hollow trunnions, through one of which the rays from the small mirror could come, would permit of operations being carried on upon a horizontal table at the end of the trunnion with great ease. Whatever might be the altitude or position of the object the photographic table would always be horizontal.

As I proposed that the telescope should not be less than 12 feet in focal length, an advantage would obviously arise from making the vertical axis of the framework beneath its centre of gravity. The observatory in which it should be placed would then require to be only one-half the diameter that would otherwise be demanded. A 12-foot tube could be worked with its frame in a cylindrical space, 13 feet in diameter and 13 feet in height.

I therefore cast a speculum of 15 inches in diameter and 2 inches in thickness. The materials employed were Minnesota copper, regarded in America as the purest commercial form of that metal, and Banca tin. Their proportions were those recommended by Lord Rosse. The cast was made in sand, 4 inches in thickness in every direction from the speculum, which was permitted to remain for two days unopened, to ensure slow cooling. It proved to be perfectly successful. The machine used for grinding and polishing it was that of Lord Rosse.

The tube of the telescope is of black walnut, bound externally by brass rings, and strengthened interiorly by iron ones. The trunnions at the little mirror are of gun-metal: they work on friction rollers of the same substance, supported on polished steel axles.

The telescope is moved in altitude, with the utmost facility, by the aid of counterpoising levers, which act perfectly, whatever the position of the tube may be. The pulleys through which these counterpoising levers work are also of gun-metal, supported on friction rollers, with polished steel axles. The motion, upon a vertical axis, is accomplished by a cast-iron shaft, 2_1 feet in length and 3 inches in thickness, working at one end on a hemispherical termination in gun-metal, and the other sustained in a strong and ground cast-iron collar.

The observatory in which this instrument is being placed is situated on a hill, 400 feet above the level of the sea, at Hastings, about twenty miles north of New York.

The edifice consists of a sunken chamber, excavated out of the solid rock. The walls of this chamber are substantially built of stone, laid in hydraulic cement. They are 9 feet high. On the top of these walls a lighter wooden edifice is raised, sufficient to make the building of the required height. The revolving roof is metallic. The ground plan is square, and 17 feet in the clear interiorly. As the frame of the telescope only requires a cylindrical space of 13 feet, the corners of the building are very available for the necessary photographic preparations.

On the top of the stone wall is placed a circular gallery running entirely around the interior of the room, and enabling the operator to have access with great facility to the photographic table and the eyepiece trunnion of the instrument. The interior of the observatory is sheathed throughout with wood.

This partly underground construction has been adopted for the purpose of ensuring a more complete invariability of the temperature of the mirror. A thorough ventilation is, however, secured whenever desirable, the local position of the edifice being such that the door of entrance is on the side of the hill at the level of the floor. The wooden sheathing is for the purpose of avoiding deposition of moisture.

At the moment of writing this paper the building is unfinished, though rapidly approaching completion. The various parts of the instrument and the photographic arrangements are provided, and no difficulty is anticipated.

This is the first observatory that has been erected in America expressly for celestial photography, and it is hoped that, considering the purity of the skies, it will yield good results.

I expect also to derive considerable advantage from the method of darkening collodion negatives by the aid of protochloride of palladium, described by me in a paper read before the American Photographical Society, and which I think in this application will permit of good proofs being taken by unprecedentedly short exposures.

On an improved Form of Air Pump for Philosophical Experiments.
By W. LADD.

On the Chromoscope. By JOHN SMITH, *M.A., Perth Academy.*

The author sent a specimen of the cut-out card, by the rotation of which, in strong light, as sunshine, he could produce various colours. There were also diagrams exhibited painted so as to represent the several colours and tints which the author had succeeded in causing to appear. The chromoscope, he said, was not the result of a happy accident, but was constructed to verify certain opinions which he had long entertained as to the cause of colour; that it not only produced colour, but explained the principle on which it was produced, and proved the necessity of introducing a negative term into the theory of colour—the purpose for which it was constructed. On the theory he said he would not enter, as he had explained it at the Meeting at Aberdeen, when he also made some experiments before Section A.

The author's object at present was to direct attention particularly to what he considered a most remarkable phenomenon connected with these experiments, which manifested itself in the change of colour which took place when the motion of the figure was reversed. The simplest illustration given, was a semidisc divided into a number of concentric rings of equal breadth, each alternate ring being painted black or cut out of the card, and the card fixed on the axle of the machine at a point, exactly equal to half the breadth of one of the rings, from the centre of the disc. When the card is made to rotate, each ring is thus divided into two equal sections, and the section of a black ring is superposed, as it were, on a white, or a white on a black when in motion; or in each revolution of the machine there is produced a sensation of light and no light on the same spot of the retina. In this experiment each contiguous ring has a different colour, one purple, the other a greenish yellow, and each alternate ring has the same colour.

Reverse the motion, the rings which were purple will now be yellow, and *vice versâ*, those which were yellow will be purple.

There was another diagram giving an analysis of this; showing how all the rings could be made of one colour, exhibiting discs wholly of purple rings, or wholly of yellow rings.

He said that in these experiments, when the revolutions of the machine were more than thirty-two in a second of time, all colour was lost to the eye; among other reasons, demonstrating to the mind of the author, that the pulsations of light are not so frequent as science represents them to be. He considered every revolution of the machine equivalent to an effective pulsation of light; and that the usual experiment of placing the prismatic colours on a wheel, and making them revolve, only proves the inability of the eye to estimate such rapid vibrations, and not the composition of white light, for the colour produced is a grey, not white, and so is the colour of his cards when in such rapid motion.

To represent refracting substances, such as prisms or other transparent crystals of any form, the author said it was necessary to make the cards revolve perpendicularly, in order to produce the form of a solid. Several of these were shown to the Section. A section of a ring produced the figure of a vase of a pink colour, with a greenish centre. A semiring produced a vase of a different form and of various colours, the brim being of a deep purple. A scroll composed of two semirings produced a strange compound figure, the predominant colour being a deep dark green.

Along these figures, in given conditions, there is a dark or a bright line, which he said was the axis of motion, and might be considered as the line of no motion or of no reflexion, or of intermittent reflexion, according to the construction of the figure. The card can be cut so as to represent both phases—the black and the coloured—in the same figure.

The author in his paper said, "Are not these phenomena very like those of polarized light?" only more astonishing, and more within the range of human research. After looking at these experiments he always felt disposed to put the question, "What *now* is polarized light?"

He also added that the horizontal and perpendicular experiments were constructed on the same principle, and that the colours are the result of the same law.

In concluding the author said, "He was anxious that philosophers should become acquainted with these experiments, as he considered that the ideas which they conveyed, and the facts which they revealed, must modify our views of some of the cognate sciences; and he was of opinion that they gave rise to a new theory of coloured refraction, but that he was unwilling to enter on the subject of refraction, until scientific men were acquainted with the phenomena of the chromoscope."

CHEMISTRY.

On Ozone. *By* Professor ANDREWS, *M.D., F.R.S., M.R.I.A.*

On the Deodorization of Sewage. *By* Dr. BIRD.

On the Quantitative Estimation of the Peroxide of Hydrogen.
By Professor B. C. BRODIE, *F.R.S.*

On some Reactions of Zinc-Ethyl. *By* G. B. BUCKTON, *F.R.S.*

Note on the Destruction of the Bitter Principle of Chyraitta by the Agency of Caustic Alkali. *By* J. J. COLEMAN.

On some remarkable Relations existing between the Atomic Weights, Atomic Volumes, and Properties of the Chemical Elements. *By* J. J. COLEMAN.

The author commenced by referring to the labours of Kopp, Schroeder, Joule, and Herapath, respecting the atomic volumes of the non-gaseous elementary bodies. The term atomic volume being defined as "indicating the space occupied or kept free from the excess of other matter by the material atom itself together with its investing sphere of heat," particular attention was directed to a fact noticed some time ago by Kopp, viz. that the atomic volumes of several elements correspond, so that they may be arranged in groups. The author then proceeded to show that, in taking a group of elements having equal or nearly equal atomic volumes, it would invariably be found that the element possessing the least atomic weight would be the most chemically active, the least reducible; and, on the contrary, the element having the greatest atomic weight would be found to be the most chemically inactive, the most reducible member of the series. These important facts were demonstrated by quoting numerous groups. Thus, amongst others, were brought forward the following, viz. :—

		Atomic weight.	Atomic volume.
1.	Manganese	27·6	44
	Iron	28	44
	Cobalt	29	44
	Nickel	29	44
	Copper	32	44
2.	Zinc	33	57
	Palladium	53	57
	Platinum	98	57
3.	Chromium	27	66
	Molybdenum	46	66
	Tungsten	95	66
4.	Sulphur	16	101
	Selenium	39·5	101
5.	Lead	103·7	114
	Silver	108	128
	Gold	197	128
6.	Chlorine	35·5	320
	Bromine	80	320
	Iodine	127	320
7.	Phosphorus	32	211
	Antimony	129	224
	Bismuth	213	270

Comparing together the members of the first group quoted, it was noticed that manganese, having the least atomic weight, is the most chemically active, the most eager in entering into combination with other elements,—iron, nickel, cobalt, and copper following in due order; whilst the facility with which the respective metals are reduced is exactly the reverse—copper with the greatest atomic weight being the most reducible, nickel and cobalt, iron and manganese following in order.

In group 2, zinc being the most active, the least reducible, and, on the contrary, platinum the most inactive, the most reducible, another illustration of the law is afforded,—the striking differences between the weight of the atoms finding its representative in the equally striking differences between the properties of the respective metals. Similar results are afforded by the study of other groups; thus in the chromium, molybdenum, and tungsten group, chromium—the most active, the most difficult to reduce, the metal forming the largest number of combinations,—possesses the least atomic weight of any member of the series, and precisely as the weight of the atom increases, in molybdenum, and then in tungsten, does the chemical activity decrease.

The group sulphur and selenium offers a pertinent illustration of the existence of the law; selenium having an atomic weight 2½ times greater than that of sulphur, being to a corresponding extent the more reducible of the two.

Lead, gold, and silver afford another illustration of the universality of the law,—lead having the least atomic weight, being the most active, the least reducible, and gold the greatest atomic weight, being the least active, the most reducible.

In the group chlorine, bromine, and iodine, the relation is very evident (the atomic volume of chlorine being that of the liquid state). Phosphorus, antimony and bismuth, and many other groups, when studied in a similar manner, confirm the generality of the law, as applied to groups of elements having equal or nearly equal atomic volumes.

These interesting results induced the author to extend the survey, and to institute a careful examination into the general relations existing between the atomic weight, atomic volumes, and properties of the whole of the elements. Considerable details were entered into, the results arrived at being summed up as follows:—

1. That elements having a small atomic weight and a small atomic volume, such as carbon, aluminium, sulphur, are difficult to reduce from their compounds. When they are isolated, they are endowed with a certain degree of permanence; but the limit of their resistibility is easily attained.

2. Elements with a small atomic weight and a large atomic volume, such as potassium, sodium, phosphorus, are invariably active, and difficult to keep in an isolated state.

3. Elements having a large atomic weight associated with a small atomic volume, such as platinum, iridium, are characterized by their capability of resisting chemical and physical agencies.

4. Elements possessing a large atomic weight, associated with a large atomic volume, such as gold, bismuth, have considerable chemical activity; but the motion of the atoms appears to be impeded by reason of their great weight.

From an accumulated amount of evidence of this nature, the author came to the conclusion that the cohesive or attractive force of the chemical atom bears some marked relation to (if it is not represented by) the actual weight of the atom, and that it is to the repulsive forces associated with the atom that we must attribute the variations in the relative volumes of the elements. The correctness of this conclusion was further confirmed by reference to the atomic constitution of a numerous series of compounds; but prior to entering into details, reference was made to those elements which possess the peculiar power of condensing upon their surfaces the molecules of the surrounding medium.

Attention was called to the fact that elements or compounds possessing a small atomic volume are invariably found to be endowed with this property, provided the atomic weight is sufficiently high.

Thus carbon, an element remarkable for its power of effecting surface condensation, not only possesses a small atomic volume, but the smallest of any known element. Again, the atomic volumes of zinc and platinum are equal, but their atomic weights differ widely, that of zinc being 33 and of platinum 98; thus in this group of elements we find that the one possessing the greatest power of inducing surface condensation is the one endowed with the highest atomic weight. Other comparisons of a similar character, and leading to a similar result, induced the author to believe that "surface condensation is caused by the cohesive attraction of the solid exerted upon the surrounding molecules of gas." This idea was put forth some time since by Dr. Faraday.

The author further extended it by supposing that the amount of the power of effecting surface condensation is dependent upon, and corresponds with, the actual weight of the atom, but that the repulsive force which keeps the atoms asunder, acting in a contrary direction to the cohesive force, prevents that cohesive force from perceptibly acting upon the molecules of the medium in which the atom is placed.

Resuming the consideration of the atomic constitution of compounds, particular attention was directed to the fact that, in a series of compounds of one metal (oxide for instance), it would be found that the compound possessing the most neutrality (the least activity) would have the greatest atomic number. The term "atomic number" was defined as "denoting the total number of elementary atoms capable of being contained within the space which would be filled by a single atom of hydrogen." The numbers brought forward by the author were quoted from Gmelin's works; but, as Gmelin's atomic numbers denoted the number of *compound* atoms capable of being contained within a given space, his (Gmelin's) numbers were by the author multiplied by the total number of elementary atoms contained in an atom or equivalent of the compound. Thus, taking equal *bulks* of lead and oxide of lead, it will be found that if the lead contains 1218 atoms, the oxide of lead will contain 1888 atoms, half of them oxygen, and the other half lead atoms. The following, amongst other series, were brought forward:—

		Atomic number.	
1.	Chromium	2333	Active.
	Sesquioxide of chromium	3610	Neutral.
	Chromic acid	2500	Active.
2.	Manganese	3220	Intermediate.
	Protoxide of manganese	2948	Most active.
	Peroxide of manganese	3777	Neutral.
	Manganic acid	?	
3.	Iron	3203	Most active.
	Magnetic oxide	3486	Intermediate.
	Sesquioxide	3715	Most neutral.
	Ferric acid	?	
4.	Lead	1218	Most active.
	Oxide ditto	1888	Intermediate.
	$Pb^3 O^4$	1953	
	Peroxide of lead	2475	Most neutral.
5.	Mercury Perchloride	878	Most active.
	Ditto Protochloride	975	Intermediate.
	Mercury	1485	Least active.

Thus in the first series quoted the compound endowed with the most inactivity, the most neutrality, possesses also, of the three, the greatest atomic number, so that in the union of two atoms of chromium with three atoms of oxygen in the production of this compound, viz. the sesquioxide, considerable condensation must occur. Chromium is chemically active in one direction, oxygen in another; and on bringing the two together, the opposing forces appear to neutralize, and balance each other; if the proportion of oxygen is increased, if one atom of chromium is united with three of oxygen, a compound is produced, not neutral, but endowed with great activity; and connected with that activity is the important fact, that its constituent atoms are wider apart than the constituent atoms of the sesquioxide, the neutral member of the series. Examining the succeeding series in a similar manner, equally striking and interesting results were obtained.

The paper concluded with the following remarks:—

To seek for an explanation of the phenomena we have been studying is a natural impulse; that an explanation cannot be given without resorting to hypothesis is very obvious; but if an hypothesis can be advanced which will connect the facts together, which will tend to enlarge our views upon the subject, and which will not be incompatible with well-known and established facts, surely that hypothesis, whatever it may be, is worthy of our present attention. There is no need to imagine the existence of any new force, any new agency; the whole of the phenomena can be satisfactorily accounted for on the supposition that the force which gives chemical activity to the atom is identical with the force which keeps the atom asunder, and that the cohesive power of the atom is represented by its weight. Thus potassium has a powerful chemical force, an electro-positive force (if we are so pleased to name it), and that force confers activity upon the atom, and by its self-repulsive nature keeps those atoms widely asunder. Chlorine has an activity of quite an opposite character, an electro-negative activity, and the self-repulsive nature of that force keeps its atoms widely apart. But when the two elements are brought together, the activity of the one destroys the activity of the other, the repulsive force of the one destroys that of the other; consequently the cohesive force (a force represented by the weight of the atom) immediately comes into play, and its effects are manifested by the great condensation, the permanent character of the resulting compound. The argument then is, that it is chemical force or electrical attraction (for the two terms are by many considered as synonymous) which determines the combination of atoms; but that, when combination actually occurs, the very force which occasions it is masked, neutralized, the elements of the compound being merely held together by the cohesive force, which corresponds with and depends upon the absolute weight of the atom.

In conclusion, the author reminded the members of the Section that the hypothesis advanced should be considered separate and distinct from the numerous facts which it had been his object to bring before their notice.

On a new Organic Compound containing Boron.
By Dr. Frankland and B. Duppa.

The authors exhibited a new body obtained by the action of zinc-ethyl on boracic ether, in which the whole of the oxygen in boracic acid is replaced by ethyl, $B(CH_5)_3$. This *boric triethide* is a colourless, mobile liquid, spontaneously inflammable. The authors are engaged in investigating the corresponding reaction on the ethers of carbonic, oxalic, and silicic acids.

Chemical Notes. By Dr. Gladstone, *F.R.S.*

The first of these notes referred to the gradual reduction of hydrate of cresyl into hydrate of phenyl and other compounds through the agency of chloride of calcium or zinc: the second described a crystalline precipitate obtained by the addition of hydrofluoric acid to molybdous chloride: the third showed by an analysis of the diffusate, that when equivalent proportions of choride of sodium and nitrate of baryta are mixed together in solution and diffused, four salts exist contemporaneously in the liquid; or in other words, a portion of each acid combines with a portion of each base; thus affording an additional evidence of the generality of the law of reciprocal decomposition.

On the Transmission of Electrolysis across Glass.
By W. R. Grove, *Q.C., F.R.S. &c.*

If glass, or an equally non-conducting substance, be interposed between electrodes in an electrolyte, so that there be no liquid communication around the edges, it is hardly necessary to say that, according to received opinions and experiments, no current passes, and no electrolysis takes place. Mr. Grove was led by some theoretic considerations to think that this rule might not be without an exception, and the following experiment realized his view:—A Florence flask, well cleaned and dried, was filled two-thirds full of distilled water, with a few drops of sulphuric acid added to it, and placed in an outer vessel, containing similar acidulated water, and which reached to the same height as the liquid in the interior. A platinum wire was passed through a glass tube, one end of which was hermetically sealed to the platinum, so that a small part of the wire projected beyond the tube. This tube passed through a cork fitted to the flask, and the platinum point was dipped into the liquid within the flask, and a similar coated wire was dipped into the outer liquid, and the two wires connected with the extremities of the secondary coil of a Ruhmkorff's apparatus. Upon the latter being excited by the battery, a stream of minute bubbles arose from both the platinum points, proving that electrolysis took place notwithstanding the interposition of the glass. The portions of the flask above the liquid, both outside and inside, were perfectly dry, so that there could have been no communication of the current over the surface of the glass. This was further proved by removing the outer wire a short distance from the liquid, when sparks passed nearly equal in length to those between wires from the terminals. As the outer wire was further removed, keeping it near the flask, sparks passed along the surface of the latter for a short distance; and as it was further removed from the liquid, still being near the flask, they ceased, thus showing that there was no passage of electricity over the upper and unwetted surface of the glass. With unacidulated water no electrolysis was observed, nor when a battery of thirty cells was used instead of Ruhmkorff's coil. In the first experiment the evolution of gas gradually diminished, and ceased in about twenty minutes, but recommenced on reversing the current. Mr. Grove concluded that the electrolysis was effected by induction across the thin glass of the Florence flask, and that its cessation indicated something like a state of charge or polarization of the surface of the glass.

On the Oxidation of Potassium and Sodium. By A. VERNON HARCOURT.

On the Composition of the Ash of Wheat grown under various circumstances. By J. B. LAWES, *F.R.S., and* Dr. J. H. GILBERT.

On the Atomic Weight of Oxygen. By Prof. W. A. MILLER, *M.D., F.R.S.*

In this paper the author pointed out some practical objections to Gerhardt's proposal for doubling the atomic number for oxygen.

It has been stated that one advantage which would be obtained by adopting the proposal, would be that it would remove all inconsistency in the vapour volumes of all compound bodies by representing them all as of equal volume.

The author commenced by showing that this assumed consistency was only imaginary, inasmuch as such uniformity does not exist in nature. In addition to the differences existing between the vapour volumes of the protoxide and deutoxide of nitrogen, similar irregularities exist in the volume of chlorous acid, and of bisulphide of mercury and some other bodies.

The practical objections, if a notation in harmony with this view were adopted, were, he stated, of still greater weight, and might be summed up as follows:—

1. The ordinary notation is known to every one who has made the science of chemistry his study. 2. All the memoirs, with the exception of a few in later years, are written in accordance with this system, and a change of notation would at once render these memoirs less easily accessible and intelligible. 3. The new notation required would not be in harmony with the language of chemistry, $N\mathit{O}$, for example, would be called *binoxide* of nitrogen, but written as a protoxide. 4. The present system of notation is capable of expressing all the later theories with perfect precision, while it is applicable to the older views; but the new notation is not applicable to many of the older views. By the ordinary notation, nitrate of potash, for instance, may be represented either as a compound of potash and nitric acid (KO, NO_5), or as a combination of potassium with nitrion (K, NO_6), or as an aggregation of particles without indicating any specific mode of combination (KNO_6); whereas, in the new notation, unless its principle is abandoned by doubling the formulæ, it is impossible that ($KN\mathit{O}_3$) should be represented as formed of potash and nitric acid. It would therefore be a retrograde step thus to exclude from our notation the power of indicating the constitution of a large class of compounds upon a view which has long been more or less prevalent. 5. Any extensive change of nomenclature or of notation, while the truth of the theory upon which it rests is still under discussion, cannot but lead to serious inconvenience. If such a practice were admitted, every new theory would be privileged to introduce a new language, which, in a continually progressive science like chemistry, would soon give way to an equally transitory successor. Chemistry, it must be remembered, is not merely a science: it is also an art, which has introduced its nomenclature and its notation into our manufactories, and, in some measure, even into daily life; it is therefore specially necessary to beware of needless innovation. Any system of notation, it must also be borne in mind, is a mere artificial contrivance to represent to the mind certain changes or certain hypotheses; and to argue for a system of nota-

tion as though it were anything more, as has sometimes been done, shows a want of true appreciation of its meaning.

The question to be considered is not simply, what is in the abstract the best mode of notation, but what, considering all the circumstances of the science, possesses the greatest advantage. That system of notation which is consistent with itself, and which lends itself most completely to the expression of the various theories and aspects of the science which have been maintained, or may be maintained, is therefore, philosophically speaking, the best. And such grounds, it appeared to the author, exist for continuing to use the system hitherto generally adopted.

The question of notation, it was observed, is entirely independent of Gerhardt's theory of the atomic constitution of the elements to which he proposes to apply it, for even those who admit the truth of his hypothesis may still express it by the ordinary mode of notation.

Remarks on the Volume Theory. *By* C. MORITZ VON BOSE.

It is endeavoured to show that the theory of volumes which separates gases from other bodies must be untrue; that there is no *generic* difference, but a difference of *degree* only between gases on the one hand, and solid and fluid substances on the other; that therefore the three states of aggregation may be considered under the same aspect.

And it is suggested that one equal standard be introduced for the specific gravity of gases and other substances; and that the attention of mathematicians be drawn to the numbers of equivalent weight and atomic volume (as obtained on using equal standard), with the view to solve the question whether those numbers being interpreted as relative distances of equivalent masses, chemical processes can be accounted for by the law of gravitation.

On a New Acetic Ether occurring in a Natural Resin.
By WARREN DE LA RUE, *F.R.S., and* Dr. HUGO MÜLLER.

On the Isomers of Cumol.
By WARREN DE LA RUE, *F.R.S., and* Dr. HUGO MÜLLER.

On the Representation of Neutral Salts on the type of a Neutral Peroxide HO_2 *instead of a Basic Oxide* H_2O_2. *By* LYON PLAYFAIR, *Ph.D., F.R.S.*

On the Analysis of some Connemara Minerals. *By* THOMAS H. ROWNEY, *Ph.D., F.C.S., Prof. of Chemistry, Queen's College, Galway.*

Connemara Andalusite.—Occurs in right rhombic prisms, having apparently the same regular measurement as the Tyrol mineral; it has a rhombic cleavage, rather eminent but interrupted; lustre of cleavage planes rather high, and somewhat resinous; colour of fracture reddish purple; the cross fracture is dull. Occurs in a vein of micaceous schist associated with quartz and a silvery mica, apparently magnesian. Faces of crystals slightly blistered.

Specific gravity 3·070.

Silica	36·92	
Alumina	60·73	
Sexquioxide of iron	·18	
Lime	1·70	
Magnesia	·30	
Traces of manganese	,,	——99·33

Connemara Pyrosclerite.—Bluish green; lustre somewhat waxy on the surface of a fracture, translucent; bears a polish, but not very high, owing to its being rather soft; contains arborizations like those of moss-agate, generally of a brown and dark green colour; readily reduced to powder, and is decomposed by strong acids without gelatinizing.

Specific gravity 2·604.

Silica	34·71	
Alumina	17·18	
Magnesia	36·56	
Water	11·49	99·94

Connemara Garnet.—Occurs in rhombic dodecahedrons with bevelled edges; faces of crystals have a metallic lustre, colour resembling bronze. The matrix appears to consist of the same mineral mixed with epidote.

Specific gravity 3·585.

Silica	39·77	
Alumina	15·49	
Sesquioxide of iron	16·27	
Lime	25·98	
Magnesia	2·06	
Manganese	·48	100·05

Analysis of the Matrix.

Specific gravity 3·404.

Silica	39·27	
Alumina	18·21	
Sesquioxide of iron	15·11	
Lime	23·45	
Magnesia	3·17	
Traces of manganese	,,	99·21

On the Composition of Jet. By THOMAS H. ROWNEY, *Ph.D., F.C.S., Prof. of Chemistry, Queen's College, Galway.*

The following results were obtained by the analysis of two specimens of jet and of a very pure coal, a portion of a fossil plant:—

	Jet No. 1.	Jet No. 2.	Coal.
Specific gravity	1·2655	1·1743	1·2860
Coke	41·19	27·38	71·65
Volatile matter	58·81	72·62	28·35
	100·00	100·00	100·00
Carbon	78·60	80·05	82·70
Hydrogen	6·21	7·21	5·42
Nitrogen	1·27	1·44	1·77
Sulphur and Oxygen	11·17	10·50	8·57
Ash	2·75	80	1·54
	100·00	100·00	100·00

On Waterproof and Unalterable Small-arm Cartridges. By T. SCOFFERN.

On a New Form of Blowpipe for Laboratory Use.

By Dr. HERMANN SPRENGEL.

Mr. SYMONS exhibited some forms of Alkalimeters suggested by Mr. Wiers.

On Thiotherine, a Sulphuretted Product of Decomposition of Albuminous Substances. By Dr. THUDICHUM.

On the Occurrence of Poisonous Metals in Cheese.
By Professor VOELCKER.

The author stated that he had detected both copper and zinc in cheese: in some specimens copper, in others zinc, and in some both copper and zinc were found. The description of cheese in which these poisonous metals were found was double-Gloucester cheese. Skimmed-milk cheese, which was likewise examined for copper and zinc, did not contain any metallic impurity. Stilton, and other varieties of cheese, have not as yet been examined; it must not therefore be inferred that cheese made in other districts than Gloucestershire contains poisonous metals. Inquiry in the dairy districts of Gloucestershire and Wiltshire has led to the discovery that in many dairies in these counties sulphate of copper, and sometimes sulphate of zinc, are employed in the making of cheese. The reasons for which these prejudicial salts are added to the cheese are variously stated. Some persons added sulphate of zinc with a view of giving new cheese the taste of old; others employed sulphate of copper for the purpose of preventing the *heaving* of cheese. Dr. Voelcker also stated that he had found alum in Gloucester cheese, and mentioned that he had learnt that in some dairies alum was employed to effect a more complete separation of the caseine from the whey.

On the Causes of Fire in Turkey-red Stoves. By Dr. W. WALLACE.

GEOLOGY.

Notes on two newly discovered Ossiferous Caves in Sicily.
By Baron F. ANCA.

FOUND in the Grotta de Olivella, near Palermo. Molar of *Eleph. Africanus* (the existing species), amidst bones and teeth of an extinct species of Hippopotamus, both in a well-marked fossil state, and infiltrated with hydrate of iron.

Grotta de San Feodora. Molar of *Eleph. Africanus*, with abundant remains; upper and lower jaws of *Hyæna crocuta*, determined by M. Lartet.

Facts go to prove continuity of land between Sicily and the African continent, probably along the line of the Adventure Bank of Admiral Smyth, stretching between Capo Bono, the promontory of Tunis and Marsala. The Admiral found only 75 fathoms sounding upon the bank; but a deep sea to the north and to the south.

Proofs of continuity with Sicily are found at Malta.

Details respecting a Nail found in Kingoodie Quarry, 1843.
By Sir DAVID BREWSTER, *K.H., D.C.L., F.R.S.*

On the Stratigraphical Position of certain Species of Corals in the Lias.
By the Rev. P. B. BRODIE, *M.A., F.G.S.*

The author first alluded to the exact position of a species of Coral found in the Hippopodium bed near Cheltenham, and another locality near Evesham, where the same form was equally abundant. Another and distinct genus, a *Montlivaltia* allied to *M. Stutchburyi*, was procured in the same bed in Warwickshire, associated with numerous other fossils, and a section of the pit was given. Other and distinct species of Corallines, one of which from Gloucestershire belongs to the genus *Cladophyllia*, were known to occur lower down in the 'Lima beds,' the probable position of the fine *Isastræa Murchisoni*, found occasionally in Worcestershire and Warwickshire. One or more additional species have been met with in the bottom beds of the Warwickshire Lias, which had not been previously observed so low down. The divisions of the Lias, which seem to be characterized by the presence of Corals, are—1, the Hippopodium bed; 2, the Lima bed; 3, the White Lias; and 4, the Guinea bed. So that it would appear that Corals are more numerous in the Lias than has been usually supposed, and that they occupy certain zones in it, which future investigations may show to be as well marked and distinctive as that of any other particular organisms.

A few Corals have been recorded from the Upper Lias, but they are smaller and less frequent than the above.

On the Velocity of Earthquake Shocks in the Laterite of India.
By JOHN ALLAN BROUN, *F.R.S.*

Mr. Mallet's interesting observations on the velocity of earthquake shocks had drawn my attention to the subject; and when earthquakes were remarked in Travancore, the part, South of India, where I resided, I endeavoured to add something to our knowledge of the subject.

Four earthquakes were perceived in Travancore during the year 1856; that to which I am about to allude was observed at the Trevandrum Observatory, August 22, where the commencement of the shock was noted accurately by the Observatory clock, at $4^h\ 25^m\ 10^s$ of Trevandrum mean time. The magnets in the magnetic observatory were dancing up and down with sharp jerks, but without any change of mean positions; a vessel containing water was wetted highest on the points to W.N.W. and E.S.E. The vibration of the bifilar magnet was 3·0 scale divisions a few minutes after the shock. On the 11th of the same month a shock had been felt at Trevandrum, and I had addressed a circular to several persons in the district for information as to the time, direction, and character of the shock: this circular had drawn attention to the questions of interest in connexion with such shocks. One gentleman at Quilon (thirty-seven miles N.W. of Trevandrum) was writing an account of the former shock when the shock of August 22nd occurred. Four gentlemen and one lady noted the time of the shock at Quilon; these times were as follows:—Mr. D'Albed'yhll and Mr. Newas (same watch), $4^h\ 20^m$; Capt. Carr, $4^h\ 25^m$; Mr. Stone, $4^h\ 19^m$; Mrs. Wilkins, $4^h\ 16^m$. A box chronometer by Dent was sent by me to Quilon, for the purpose of comparing it with the different watches or clocks used in the determination of the time of the shock: the rate of the chronometer was +8 seconds, and the error was determined before and after the comparisons, which were made August 27th. The following are the facts connected wth the observations:—Mr. Newas had set his watch, on the 17th of August, to $6^h\ 0^m$ at sunrise; allowing for the height of the chain of Ghats where the sun rose, I have computed that sunrise must have been about 3 minutes before six o'clock: the watch had been allowed to run down after the shock, so that it could not be compared with the chronometer. Supposing the watch without any marked rate, the Trevandrum mean time of the shock was $4^h\ 18\frac{1}{2}^m$. Mr. Stone had set his watch August 17, by the time of the Trevandrum Observatory (where a ball is dropped daily at eleven o'clock). When compared with the chronometer, it had gained $3^m\ 35^s$ giving a daily rate of about $+21^s{\cdot}5$; so that on the 22nd the error of the watch must have been about $1^m\ 47^s$, and the shock must have occurred about $4^h\ 17\frac{1}{4}^m$ Trevandrum mean time. This is by far the most important observation; the others can be considered only as approximate determinations. Capt. Carr's watch was found fourteen minutes fast of Trevandrum time on the 27th; supposing the rate zero, the time of shock was $4^h\ 11^m$. Mrs. Wilkins's clock had been compared with the mess clock of the native regiment at Quilon, which was regulated by persons proceeding from Trevandrum, with the Observatory time, and which was found correct when compared with the chronometer. Mrs. Wilkins's clock was three minutes slow of Trevandrum mean time, making the time of the clock $4^h\ 19^m$. The four observations, therefore, corrected to Trevandrum mean time, gave—

	h m		h m
Mr. Newas.............	4 18½	Mrs. Wilkins...........	4 19
„ Stone...............	4 17¼	The mean gives..........	4 16½
Capt. Carr.............	4 11		

There can be no doubt that Mr. Stone's observation is the most trustworthy, as his time depends on two comparisons with the Trevandrum Observatory, viz. on the 17th and 27th; and the deduced error for the middle of the interval (the 22nd) cannot be far from the truth. Mr. Newas's observation, which agrees with it within about a minute, depends wholly on the observation for the sunrise; it is so far confirmatory. Rejecting Capt. Carr's observation, as differing too much from the others, the mean of the remaining three is $4^h\ 18\frac{1}{4}^m$.

If we suppose the shock to have travelled in the direction from Quilon to Trevandrum, which does not differ much from that indicated by the vessel of water, and take the distance at thirty-seven miles, we obtain a velocity of propagation of 470 feet per second; and if we take the latest result at Quilon, or 4^h 19^m, we have still a velocity of only 530 feet per second--little more than three-fifths of that found by Mr. Mallet in wet sand. If we take the W.N.W. as the direction of propagation of the shock, or any other than that direct from Quilon, the velocity will of course be diminished. It should be remarked that the laterite, which forms the upper stratum (about 30 feet deep) between Quilon and Trevandrum, is a clayey rock, in a semi-pasty condition of perhaps the lowest degree of elasticity; and the laterite reposes in some places on strata of sand and clays.

On the Course of the Thames from Lechlade to Windsor, as ruled by the Geological Formations over which it passes. By the Rev. J. C. CLUTTERBUCK, *M.A.*

The tortuous course of the Thames between Lechlade and Windsor shows that there must be some physical cause which obliges it to deviate from the straight line it would naturally take to its outfall. This is found in the obstructions encountered in its passage over or through the various strata. From Lechlade to Sandford the river finds its bed in the Oxford clay; it then passes through a narrow gap in the middle oolite to the Kimmeridge clay, holds its course on that clay, under the escarpment of the Iron-sand in Nuneham Park, turns the escarpment at Culham, passes to the Gault at Appleford, touches a ledge of the Iron-sand at Clifton Hampden, returns to the Gault, enters the Greensand near its junction with the Thame stream, passes to the Chalk, in which it finds its bed to the point,—which is the limit proposed for consideration. The natural obstructions are found at the junction of the different strata. The quantity of water flowing down the river, whether issuing in perennial springs, or thrown from the surface in flood, is due to the geological condition of the district. The tributaries or feeders discharge more or less of perennial or flood water, as they carry the water from permeable or impermeable strata. The flooding of the district necessarily affects the sanitary condition of Oxford. The city itself is placed on a bed of gravel, overlying the Oxford clay, the surface of which undulates so that the water is stanked back in the gravel; it was cutting through one of these undulations, in carrying out the Jericho drainage, that deprived many wells in Oxford of their water. As this bed of gravel extends beyond the limits of the city, on the subsidence of the floods, the water filtrates through the gravel, and thus noxious evaporation is diminished. Considerable accumulations have raised the bed of the river in many places, evidence as to the date of which is found in antiquities which have been discovered when constructing locks or weirs, or in dredging for gravel. At Sandford, arms of the time of Charles I. have been found 8 feet below the river-bed, relics of greater antiquity and at various depths have often been found in other places, where the bed of the river has been raised, or, as in some cases, entirely changed its course. The phenomenon of the formation of ice at the bottom of the stream, when the temperature falls to 20 Fahr., and the transportation of stones from the bottom by the ice rising to the surface, adds to the natural obstructions in the stream, and hinders the passage of the flood-waters by which so much damage has been done at various times in the neighbourhood of Oxford. The paper, which entered into full details, was illustrated with a map, sections, and diagrams.

Photographs of a Paddle of *Pliosaurus* of great size, found at Kimmeridge, were exhibited by Mr. R. DAMON, of Weymouth.

Remarks on the Elevation Theory of Volcanos.
By Professor DAUBENY, *M.D., F.R.S.*

This paper was chiefly intended as a protest against the assumption of certain geologists, that because it had been shown, more especially by Sir Charles Lyell in his memoir published in the 'Philosophical Transactions' for 1858, that sheets of compact lava have been formed on steep inclines, it therefore followed, that all volcanic mountains have been built up by a series of successive eruptions.

Not denying that this explanation may serve for the oldest, as it certainly does for the more recent beds, which constitute such mountains as Etna and Vesuvius, the author contended that it is not applicable to the celebrated case of Jorullo, as described by Humboldt, nor yet to the volcanic islands thrown up in deep water at various times during the historical period.

He was also disposed to refer the four trachytic Puys near Clermont, in Auvergne, as well as the still loftier Cones composed of the same material in the Andes, which Humboldt describes, rather to the upheaval of a softened mass of rock, than to the outburst of liquid lava.

He appealed also to the crater-lakes in the Eifel country and elsewhere, as furnishing cases of upheaval, even where no lava had been ejected; and argued, that so long as the idea of paroxysmal action continued to be entertained with reference to rocks in general, it was probable that volcanic countries, above all others, would be subject to such operations.

On the Mode of Flight of the Pterodactyles of the Coprolite Bed near Cambridge. By the Rev. J. B. P. Dennis, *F.G.S.*

Coprolitic remains of Pterodactyle bone have afforded an opportunity of studying its microscopic characters, and this had led to the present attempt to show from the analogy of other flying animals, from the different modes of flight among birds, from the apparent adjustment of the haversian canals thereunto, and the harmonious perfection of the skeleton with the adaptation of the pectoral muscle to the same (so that even the humeral process of its attachment has its marked characteristics), that these and other analogies lead to the inference that considerable knowledge even of the mode of flight of this extinct reptile may be obtained from the study of its microscopical bone structure. In elucidation of this subject, a brief account was given of the structure of the wing-bones of a bird, and of the mode of flight of the Gull, a bird distinguished for its elasticity and endurance on the wing, and in other respects very suitable for illustrating the subject.

A description was then given of fragments of Pterodactyle bone obtained by Mr. Barrett from the coprolite bed, most of which were portions of wing-bones of very thin texture. It was also shown that the Pterodactyle required not to be encumbered with muscular legs, and thus the vastus was only sufficiently developed to enable the animal to spring from the ground preparatory to flight (as the form of the femur also seemed to indicate); also the biceps, semitendinosus, &c., or their analogues, did not require any great development; while the gastrocnemius, as it would assist in the spring, was probably on that account fairly represented. The pectoral muscle, following the saurian type, must have been less voluminous than that of birds, flatter, with its greatest development in front, and in position comparing somewhat with that muscle in gulls and owls, birds of elastic but not rapid flight. The Pterodactyle was also shown to agree more with birds than with bats, especially in its omoplate, while the absence of a fercula implied no similar volume of muscle; the bones in like manner were permeated by air, or if some were not, they were yet filled with a light fatty substance or marrow to give additional strength to their light texture; and though the natural weakness of its muscular powers was considerable in comparison with birds, yet this was balanced by an extremely light framework, the weight of which predominated in front, where the muscular force was more directly antagonistic; and above all, the admirable microscopic structure of its bone eminently conduced to its powers of flight. Delicate in the extreme to the unassisted eye, when examined under the microscope, the bone is found to contain numerous and large haversian canals in a very marked degree, comparing in their arrangement with those seen in the wing-bones of gulls; also lacunæ well displayed, larger than those of a bird of flight, long and fusiform. From this correspondence of the characters of the haversian canals, of which illustrations were given, an inference seems capable of being drawn in reference to the flight of these large Pterodactyles, which, if they did not possess the dash of the falcon or the impetuosity of the wood-pigeon, yet sailed gracefully over primæval seas with a lightness and buoyancy, as it would seem, analogous in some degree at least to the conspicuous grace of the gulls, which are the present ornament of our coasts. So in every respect is seen the wisdom displayed in the adaptation of means, each inadequate in itself, and the result is the production of one of the strangest anomalies, of which, if we had not had the clearest testimony, the imagination would have failed to picture,—a true Pterosaurian, in some respects perhaps more wonderful in its construction than bats or even birds, and being as fully capable of flight as they, teaching us how great are the resources and how infinite the wisdom of Him who has done all things well.

On the Corrugation of Strata in the Vicinity of Mountain Ranges.

By the Rev. J. Dingle.

This paper was in continuation of an attempt to determine the mechanical causes of the formation of the earth's crust, and to trace its progress. The author described the varying forms of flexure, diminishing in intensity with their distance from the igneous axis, which characterizes the strata in the neighbourhood of the mountain chains; and showed how this form would arise from the action of the molten interior, by referring to the result of experiments upon the action of fluids under like conditions. He expressed his obligations to Professor Rogers for the valuable information which he had derived from a paper of his in the Edinburgh Transactions, but demurred to some of his hypotheses. Flexures at definite points must be produced by repeated or continued pressures, and not by paroxysmal action. The latter chiefly spends itself in earthquakes and volcanoes, which, upon the whole, can produce no continuous change of form. The two forces, however, seem to be intimately related to each other; and if we suppose the one to be only the other in excess, we are supplied with a simple explanation of the connexion between the corrugated mountain chains and the lines of earthquakes and volcanoes.

As a corollary from the above views, it might be observed that they destroyed the idea of any distinct theory of volcanoes of elevation or eruption, as the quantities of elevated or ejected matter in the case of a fissure or a ruptured corrugation might be in any proportion whatever to each other.

Remarks on the Ichthyolites of Farnell Road.

By Sir Philip de M. Grey Egerton, *Bart., F.R.S.*

At the Meeting of the British Association last year at Aberdeen, I had an opportunity of examining several specimens of the small fishes found in the Old Red Sandstone deposits of Farnell, and in the discussion which ensued upon the reading of Mr. Mitchell's paper, I took occasion to remark upon their several characters. I then stated that all the specimens I had seen belonged to the family *Acanthodei*, and the great majority of them to the genus *Acanthodes*, representing, however, a new species of the genus. I proposed inconsiderately to name this species *A. antiquus*, a very inappropriate title, inasmuch as two contemporaneous species were subsequently exhibited by Mr. Peach. As, however, this name has not appeared in print, I propose to cancel it, and substitute *A. Mitchelli*, as the original or type-specimen is in the possession of the Rev. Hugh Mitchell, of Craig. The other specimens I described as constituting a new genus corresponding in many characters with *Diplacanthus*, but differing in the shortness and position of the spines of the fins. I proposed for this genus the name *Brachyacanthus*.

The specimens from the same locality recently received from Mr. Powrie are of the same species as those examined at Aberdeen. I learn, however, in a letter received from Mr. Powrie since I have examined his specimens, that he has in his possession others comprising at least two very distinct species of *Diplacanthus*, one remarkable for its very strong anterior dorsal spine, and fragments belonging probably to other species. Mr. Mitchell also writes that another locality has been found rich in remains of Acanthodian and other fishes. Under these circumstances it would be premature to enter into any detailed account of these interesting ichthyolites. As the materials, however, are sufficiently complete, I append a short description of *Acanthodes Mitchelli*.

The specimens I have examined vary in length from 2 to $2\frac{3}{4}$ inches. The one I have selected for description attains nearly the latter dimensions. The greatest depth of the trunk occurs in advance of the ventral fins, where it measures rather more than half an inch. The head is small and elegantly sculptured. It measures about $\frac{1}{5}$th of the total length. The outline of the body is very graceful. It is fusiform anteriorly, and tapers gradually posterior to the insertion of the highly heterocerque tail. The orbit is placed very forward, and is embraced by the remarkable bony plates described by Römer as characteristic of the genus. The peculiar structure of the gill-covers also corresponds with that of other species of *Acanthodes*. The pectoral spines are long and curved. The other fin-spines are slender and straight. The species differs from all others of the same period in the ornament of the head-bones and the form of the body. It is distinguishable also from *Acanthodes Peachi*, a new species discovered last year by Mr. Peach in the Caithness flags, by the form of the spines, the pectoral spines in the latter being straight, and the dorsal and anal spines curved.

Photographs of Fishes, from Farnell in Fifeshire, were exhibited by Mr. W. Rogers, of Montrose.

On a New Form of Ichthyolite discovered by Mr. Peach.

By Sir Philip Egerton, *Bart., M.P., F.R.S.*

This fossil fish, discovered by Mr. Peach in the Caithness flagstones, is chiefly remarkable for the structure of the fins. The dorsal and anal fins are supported upon three interspinous bones in each organ, from which the fin-rays spread in tufts. A similar structure prevails in the caudal fin. It is nearly allied to *Dipterus*, and probably belonged to the Cœlacanthoid family. The name *Tristichopterus alatus* has reference to the peculiar structure characteristic of the genus.

On Circular Chains in the Savoy Alps.

By M. A. Favre, *Professor at the Academy of Geneva.*

The object of this memoir is to describe the peculiar structure of the mountain chains in Savoy, on the left bank of the river Arve.

This region may be divided into several districts, which, in passing from Mont Salève to Mont Blanc, are as follows: (1) the Tertiary, (2) the Cretaceous, (3) the Jurassic, and (4) the district of crystalline rocks. M. Favre treats of the second of these, in which the mountain chains surmounted by precipitous peaks are composed in great part of cretaceous rocks. This district is about 49 kilometres long from the river Arve to the lake of Annecy, by 24 broad. The loftiest mountain attains the height of 2760 metres above the sea-level, and there are several other summits between 2300 and 2400 metres high. The geological formations which constitute this district are,—1. the Jurassic which occupy a very limited space; 2. the Neocomian; 3. the Urgonian, which forms enormous escarpments, and constitutes the crest of the mountains; 4. the green sandstone; 5. the chalk; 6. the nummulite limestone; 7. the alpine macigno, which at its base contains various marls with fish scales, and above marls and sandstones associated with the Taviglianas freestone which is a species of volcanic cinder.

One of the valleys of this district, that namely of Thônes on Grand Bornant, is a longitudinal valley; the others are transverse valleys watered by rivers arranged almost like the radii of a circle. This peculiarity in the direction of these rivers depends on that of the mountain chains; for the rivers in general cut the chain perpendicularly to their axes, and with the exception of Mont Charvin à la Pointe Percée, all the mountain chains of this district, and especially those on the borders, are in the shape of a quadrant, and lie in every direction that can be found in a quadrant. It is to these chains that M. Favre has given the name of circular chains.

Mountain chains have long been remarked whose axes are more or less undulatory, others separating from a common trunk like the branches of a tree; strata, moreover, have been observed that rise to the surface of the ground in the form of the bottom of a boat; and the opposite phenomenon has likewise been observed, that namely of a mountain chain in the form of a vault or half cylinder sinking so as to disappear in the plain; but M. Favre is of opinion that the fact to which he has called attention is different from any of these, insomuch as it refers to entire chains, which are not only curved, but curved to such a degree that their extremities are at right angles to each other.

M. Favre concludes his essay by calling attention to the fact that the chains of the Alps display the closest orographical resemblances to those of the Jura, which are now well known. Although the displacement of the soil is much greater in the Alps than in the Jura, in both are found groups either entire or broken, which in the latter case disclose in their interior, one, two, or three of the strata below that which forms their crest; in both are found combes, ravines, and valleys of the same form. M. Favre believes that the identity of these forms leads to the conclusion that the elevation of the Alps and the Jura is due to causes of the same nature.

On some Transformations of Iron Pyrites in connexion with Organic Remains. *By* ALPHONSE GAGES.

I have to direct the attention of the Section to some facts regarding the transformation of iron pyrites connected with fossil graptolites from Tinnaglough, Co. Wexford.

These peculiar characteristic fossils of the Lower Silurian schists are found very often transformed into rhombic iron pyrites.

This transformation into pyrites is now, since the observations of Pepys and others, easily accounted for, and therefore I have not to dwell upon it.

Looking over some of those schists, we may observe the various transformations the fossil has passed through until it entirely disappears from the schist.

I. Fossil exhibiting some traces of organic matter, and not mineralized by pyrites.

II. The same fossil transformed into rhombic iron pyrites.

III. The transformation of the pyritic fossil into a corresponding fossil of aluminite.

IV. A mere cast of the fossil, or indication of one only remaining.

And lastly, in some neighbouring joints of the schist, a thin layer of sesquioxide of iron, alum, or of aluminite generally accompanied by free sulphur.

Analogous phenomena may be observed in other fossils of the carboniferous formation, and especially in the lower limestone shale near Drogheda.

One may observe in some points in which the fossil has been completely obliterated, a thin mineral layer of aluminous compounds, varying more or less in their chemical constitution.

These facts are very suggestive in this sense, that if the processes of mineralization going on for ages have served to preserve many forms of organic beings, so also they serve to destroy them.

We witness every day the destruction of a great number of pyritic fossils by the mere action of air, and their transformation into sulphates, and sometimes, according to local circumstances, into sulphates and free sulphur. Whenever sulphur occurs in deposits containing organic remains, we are induced to believe that it has been formed in somewhat a similar way.

On Snow Crystals observed at Dresden. *By* Dr. GEINITZ.

On the Silurian Formation in the District of Wilsdruff. *By* Dr. GEINITZ.

The discovery of Graptolites in the Lydit and Phthanit, lately made in the district of Wilsdruff, near the villages of Limbach, Lotzen, and Lampersdorf, a neighbourhood where the azoic and metamorphic clay-slates, sometimes with true chiastolith, are predominant, now combines a considerable part of the most northern part of the Saxon Erzgebirge with the Silurian.

These black schists of Graptolites, with *Monograpsus triangulatus*, Harkness, *Mon. priodon*, Bronn, *Mon. Becki*, Barrande, and *Mon. nuntius*, Barrande, are continued in the schists of Graptolites on the northern slope of the Erzgebirge near Langenstriegis, not far from Frankenberg, Ober-Cainsdorf near Zwickau, Ronneburg, Oelsnitz, Heinrichsruhe near Schleiz, and various places of the district called Voigtland, where they indicate the same geological horizon as in Bohemia, the upper part of the Lower Silurian, or the base of the Upper Silurian of M. Barrande. All the species found in Saxony are described in the author's 'Monograph of Graptolites,' Leipzig, 1852.

On the Metamorphic Rocks of the North of Ireland. *By* ROBERT HARKNESS, *F.R.S., F.G.S., Professor of Geology in Queen's College, Cork.*

Almost the whole of the county of Donegal is occupied by rocks which appertain to the metamorphic series, consisting of gneissose rocks associated with limestones and quartz rocks. The relation which these several rocks bear to each other, and to the syenitic masses which in some cases are found accompanying them, is well exhibited in the sections along the north side of Lough Foyle, from Malin Head to Inishowen Head. On the S.W. side of Malin Head a protrusion of syenite is seen, which forms an axis in this portion of Ireland; and reposing on this axis there are found, first and lowest, quartz-rocks, succeeded conformably, on the north side, by flaggy gneiss; and on the southern side a like occurrence commonly takes place. In some localities, on the southern side of this axis, limestone frequently intervenes between the underlying quartz-rocks and the overlying gneissose strata; and the limestones, scattered in small patches among the metamorphic rocks of the north of Ireland, occupy this position with reference to the rocks of this character. The arrangement of these rocks in this part of Ireland, as regards position, is as follows: the lowest quartz-rocks succeeded by limestones, which are not persistent, but upon which, when present, great masses of chloritic gneiss are seen having usually a S.E. dip, often the result of reversed flexures. Through these rocks, which are the Irish representatives of the strata of the Grampians, numerous trap dykes occur.

Notes on the Geology of Captain Palliser's *Expedition in British North America. By* Dr. HECTOR.

The following remarks are explanatory of a section commencing at Lake Winnipeg, continued along the basin of the Saskatchewan River to the Rocky Mountains, and from thence to Vancouver's Island. This section is only intended to represent the more general results of this geological exploration, as a preliminary to the reports which are in preparation.

The rocks east of Lake Winnipeg have been fully described by geologists. They are a part of the so-called Laurentine chain, and consist of granite and metamorphic rocks. On these lie Silurian limestones, cherty, and of magnesian character, with corals and shells, easily referable to Silurian types. Above these Mr. Hind has found Devonian strata, of which, however, I saw no trace farther south. The supposed line of their outcrop is marked by salt springs.

The first well-defined strata in the Prairie country occur 150 miles west of Red River, and are indurated olive shales, with ferruginous bands and traversed by veins of clay ironstone, with a few small fossils, chiefly fish-scales, and a small, neat species of nucula. They are a deep-water deposit.

At the elbow of the Saskatchewan River, the banks are formed of purple laminated clays, with lines of Septaria of various sizes. These Septaria yield fossils, which are truly cretaceous forms. The most common are *Baculites* and *Inocerami*. These Septaria clays are also deep-sea deposits. They are again met with on the north branch of the Saskatchewan, 150 miles to north-west, and the course of this river is for some distance determined by these soft beds. At the Snake Portage, in lat. 54° N., I thought I observed them overlaid by thick grits and clays, which must be next described; but of this junction I am not certain, and the dip is so slight that they may be even underlaid by these grits.

The latter strata, in beds often 200 feet thick, form high ridges, which range north and south, crossing both Saskatchewans, and also the Red Deer River, at the Nick Hills. They form mainly two parallel ranges, and between them occur clays with coal or lignite beds from 2 to 10 feet thick, and consistent in their strike from north-west to south-east. This coal is used at Fort Edmonton, and burns pretty well. Some vegetable impressions, like those of cypress and dicotyledonous leaves, are found in the shale, but no other fossils.

As these coal-beds and shales occur in the river-beds, and at low levels compared with the surrounding prairie, it is manifest that the surface-beds of which these are composed, are of later age; but whether conformable with them or not, I am unable to say.

To the south-east of the elbow of the Saskatchewan, at the base of the Coteau de Prairies, and at a locality on the Souris River known as the *Roche Percée*, is a group of marls, with limestone bands, containing so much iron as to weather of a bright vermilion colour, and ash-coloured arenaceous clays, with their bands of lignite and silicified wood. Selenite crystals are abundant in these marls, often clustered in stellate forms. They are mixed with bands of grit, from a few feet to 30 feet in thickness; and these being generally of a soft nature, with indurated portions, weather out in the most grotesque forms.

On the higher grounds traversed by Battle River, and again on Red Deer River, where they are seen to rest on the great lignite group, are also beds of marl, limestones with iron like those of the Roche Percée, beds of lignite and true brown coal, with silicified trees, and abundance of fossils of an estuarine character. Among these latter are oysters, a good deal like the Pacific species, *Mytili*, *Cyprina*, and other marine forms in some beds; and in others *Paludina* is the prevalent fossil. On the very high grounds (such as the Ochèschis or Hand Hills and the Cyprees Hills), these strata pass up into sands, gravel, and beds of coarse shingle, which, at the same level (4000 feet above the sea), skirt the base of the Rocky Mountains, and there rest on the edges of upturned strata of various ages.

All the strata which I have mentioned are covered with a mantle of drift, which does not rise much above 3000 feet; but near Battle River there seems to be a group of deposits which I have termed Tertiaries of the low grounds.

The strata composing the Rocky Mountains may be briefly described as follows:—In crossing from the east, thirty or forty miles before entering the range, beds of grits and shales are observed much disturbed, but obviously dipping to the east. From a level of 4000 feet above the sea, the mountains rise as parallel ranges of cliffs from 3000 to 4000 feet in height. The first five or six of these ranges are composed of blue crystalline and earthy limestone in bold plications, including portions of the same grits and clays that are seen along the eastern base. This group of strata must be several thousand feet in thickness, and contain fossils of Carboniferous age. To the west, and forming the range which in general determines the water-shed, is an immense thickness of quartzite and conglomerates, not much altered, and apparently horizontal. A wide longitudinal valley marks the line between this formation and the last mentioned, and is probably the site of a great fault.

On descending the western slope of the mountains, while in the bottom of the valleys are vertical talcose slates, the higher parts of the mountains are composed of the same strata which form the eastern ranges, until the great valley is reached, which the Columbia and Kootanie rivers traverse, while their course is parallel to the range.

West of this a belt of slates and semi-metamorphic rocks was crossed, followed by granite with true metamorphic rocks containing serpentine and marble, which brings us to Colville.

South and west of this plain commence the great superficial floes of basalt with beds of tufa, which have emanated from the flanks of the Cascade range. The Cascade range itself consists of syenite and slates, with volcanic rock of recent date.

The greater mass of Vancouver's Island is composed of the same metamorphic strata as at Colville; but along both sides of the Gulf of Georgia, which separate it from the mainland, and also forming the islands in that gulf, occur beds of grits and coarse conglomerate, much disturbed and resting on volcanic rocks, and containing the well-known deposits of coal and lignite as at Nanaimo and Bellingham Bay. These coal-bearing grits at Nanaimo, I found to be overlaid by Septarian clays, such as those I have found to the eastward of the Rocky Mountains, and containing the same cretaceous fossils, comprising *Baculites* and *Inocerami*. These clays are observed, again, to be covered by grits. Fossils were obtained at some distance below the coal at the base of the whole group, which have not yet arrived in England for examination. They are, however, either lower cretaceous or oolitic forms.

Remarks on the Geology of New Zealand, illustrated by Geological Maps, Drawings, and Photographs. By Prof. F. VON HOCHSTETTER.

Some Observations upon the Geological Features of the Volcanic Island of St. Paul, in the South Indian Ocean, illustrated by a Model in Relief of the Island, made by Capt. Cybulz, of the Austrian Artillery. By Prof. F. VON HOCHSTETTER.

On the Six-inch Maps of the Geological Survey. By E. HULL, *B.A., F.G.S.*

On the Blenheim Iron Ore; and the Thickness of the Formations below the Great Oolite at Stonesfield, Oxfordshire. By EDWARD HULL, *B.A., F.G.S.*

The author described the position of this iron ore as occurring in the upper part of the Marlstone or Middle Lias, along the valley of the Evenlode, near Charlbury; its outcrop being traceable for some distance along both banks of the river. It is identical in geological position with the Cleveland ore of Yorkshire, and similar in its mineral character. The bed varies in thickness from 10 to 15 feet, and the ore is capable of being worked to an unlimited extent by tunneling into the hilly side from the outcrop. The fossils, which are local, consist of the usual Marlstone species, as *Rhynchonella tetrahedra*, *Terebratula punctata*, &c.

Mineral Character.—At the outcrop, the iron-bed presents a rich ferruginous aspect; but when followed to some depth below the surface, the original colour is found to be olive-green, and under the magnifying glass the stone appears oolitic. In this state the ore is probably a carbonate and silicate of iron—the latter imparting a green tinge. When exposed, it passes into a hydrated peroxide of iron. The remaining constituents are carbonate of lime, 10 per cent.; silica, 12 per cent.; alumina, 7·8 per cent. Phosphoric acid is only present in minute quantity, viz. 0·55 per cent. The chief market for the ore is expected to be South Wales*.

Thickness of the Formations below the Great Oolite at Stonesfield.

For the purpose of ascertaining the depth of the iron-bed below the Stonesfield slate, the Duke of Marlborough directed that one of the slate pits should be continued downwards till the ore was reached. This has not been accomplished; for on reaching at a depth of 120 feet the Upper Lias Clay, the water flowed in so plentifully that the men were drowned out. With the assistance of numerous sections near Fawler, the deficiency in the series may be supplied; and the following are the results:—

Succession of Strata at Stonesfield.

	feet.
GREAT OOLITE. 1. *Upper Zone.*—White limestone, resting on calcareous shales and marls (total thickness about)	100
2. *Lower Zone.*—Sandy shales, flags, and shelly oolite, with a band of "Stonesfield slate" at 10 feet from the top	80
INFERIOR OOLITE. *Upper Ragstone* (zone of *Ammonites Parkinsoni*).—Large-grained, rubbly oolite, very fossiliferous, with *Trigonia costata*, *Lima gibbosa*, *Terebratula globata*, *Clypeus Plotii*	30
UPPER LIAS CLAY.—Blue laminated clay	6
MARLSTONE. 1. *Iron-bed.*—Massive ferruginous rock, with *Rhynchonella tetrahedra*, &c.	10–15
2. Sands, with iron concretions atop	15
LOWER LIAS CLAY.—Thickness unknown.	

Comparing the development of these formations with that which they attain in Gloucestershire, the author showed that they all tended to decrease in thickness when traced from the north-west towards the south-east of England, and contended that these facts bore out the theory which he had on previous occasions endeavoured to demonstrate, that all the secondary rocks of England undergo attenuation towards the south-east. The following comparison had been arrived at from carefully measured sections:—

Comparative Sections.

		Gloucestershire. Maximum thickness. feet.	Oxfordshire. Minimum thickness. feet.
Fuller's Earth		40	0
Inferior Oolite		264	5
Upper Lias	Sands	20–50	0
	Shale	380	6
Marlstone		250	25
Lower Lias		600 (nearly)	?

The author considers it probable that under Oxford the Great Oolite is separated from the Lower Lias by not more than 25 feet of strata, of which the Marlstone forms the greater part.

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* As this ore extends under the property of the Duke of Marlborough, the author has named it the "Blenheim iron-ore;" and for fuller details refers to his memoir, "The Geology of the Country round Woodstock," Mem. Geol. Survey, 1857.

Notes on some Points in Chemical Geology.
By T. STERRY HUNT, *F.R.S., of the Geological Survey of Canada.*

Dolomites and Gypsum.—Mr. Sterry Hunt has shown, from the mode in which dolomites occur and from the phenomena presented by their associated fossils, that these magnesian rocks cannot have been formed by the alteration of pure limestones, so that the theories of Von Buch and Haidinger, proposed to explain their formation, are really in nowise applicable. He has further shown, that in the famous experiment suggested by Haidinger and performed by Von Morlot, who asserted that by the action of sulphate of magnesia, in presence of water in an excess of carbonate of lime, at 200° C. under pressure, there is formed sulphate of lime and a double carbonate of lime and magnesia, the fact has been overlooked that in reality no double carbonate is obtained, but only a mixture of anhydrous carbonate of magnesia with carbonate of lime, and consequently not a dolomite, which is a chemical compound of the two.

In Marignac's modification of Von Morlot's experiment, where the chloride is substituted for the sulphate of magnesia, Mr. Hunt finds that a variable portion of this double carbonate is really formed, and remains mingled with the excess of carbonate of lime and anhydrous carbonate of magnesia, which is also a result of the reaction as before. Charles Deville's late experiments, in which fragments of limestone were impregnated with magnesian solutions, and heated at the ordinary pressure, with formation of soluble lime-salts and magnesian carbonate, are but imperfect repetitions of Von Morlot's and Marignac's processes, and none of these are applicable to the great majority of cases in which pure and magnesian limestones are associated in such ways as to show that they have been successively deposited from water, the latter sometimes enclosing pebbles and fossils of pure carbonate of lime.

Mr. Hunt proceeds to show that, when mixtures of amorphous hydrated carbonate of magnesia with carbonate of lime are heated under pressure to a temperature of 300° to 400° F., direct combination ensues, and dolomite is formed; and he gives reasons for supposing that this combination may take place slowly at much lower temperatures.

It was, however, necessary to find a source for the magnesian carbonate which had formed these magnesian sediments, and here Mr. Hunt has signalized a remarkable and hitherto undescribed reaction, by which carbonate of lime decomposes sulphate of magnesia, not with the aid of heat and pressure as in Von Morlot's experiment, but at the ordinary temperature. When a solution of bicarbonate of lime is mingled with a liquid containing sulphate of magnesia, a double decomposition takes place, and by evaporation at temperatures between 90° and 180° F., the lime is deposited in the form of gypsum, a very soluble bicarbonate of magnesia remaining dissolved, which is precipitated by further evaporation. If we conceive the carbonate of lime to be furnished by springs falling into a closed lake or basin, the carbonate of magnesia would be precipitated in a state of mixture with carbonate of lime, thus giving the elements of the dolomite which is always associated with stratified gypsum.

Mr. Hunt has further shown that, by the action of waters containing alkaline carbonates upon sea-water, the lime is first precipitated, and at length there is formed a solution of bicarbonate of magnesia. To this agency he ascribes the vast deposits of magnesian rocks which exist independent of gypsum, and which sometimes contain an excess of carbonate of magnesia over that required to form dolomites, or lime being absent, are magnesites.

The part which carbonate of soda has played in giving rise to carbonates of lime and magnesia must, according to Mr. Hunt, have been very important in former periods. The source of this has been the decomposition of felspar, which, in being reduced to clays, have lost the whole or a part of their soda in the form of silicate, which, converted into carbonate by the carbonic acid of the atmosphere, is now represented by the sea-salt of the ocean and the carbonates of lime and magnesia of the rocky strata. Clays and argillites are unknown in the vast thickness of crystalline rocks which constitute in Canada the Laurentian system, lying beneath the Lower Silurian series. In these oldest rocks, the alumina exists in the form of felspar, in great part with a base of soda; but in the Silurian rocks, when altered, aluminous silicates abound, such as chlorite, epidote, and alumina-garnet, and in those strata where lime and magnesia are absent, chloritoid Andalusite, staurotide, and kyanite. These minerals, which are only formed in aluminous sediments that have lost their alkalies, become more and more abundant on the newer strata.

The consideration of the composition of mineral springs, as Mr. Hunt has remarked, shows that the solvent action of water removes from sediments chiefly soda, lime, and magnesia, and with the concurrence of organic matter, oxide of iron, so that the more permeable strata, and generally more siliceous, retain scarcely any other bases than alumina and potash; the argillaceous and less permeable beds, on the contrary, retain the whole of their bases. The operation of processes continually going on in nature therefore tends to divide the silico-argillaceous rocks into two classes, whose metamorphism and displacement will give rise, on the one hand, to granites and trachytes, and on the other, to rocks made up of basic felspar and pyroxenes.

The author regards all the so-called igneous rocks as altered and translated sediments, and distinguishes them by the name of *exotic rocks*, from the same sediments altered *in situ*, which may be called *indigenous* plutonic rocks. He insists upon the fact that the chemical composition and, for the most part, the lithological characters of all the varieties of intrusive rocks may be found represented in metamorphosed sediments.

Mr. Hunt has called attention to the fact, that as long ago as 1834 Keferstein advanced the opinion that all plutonic rocks are only altered sediments, and thus anticipated in part Sir John Herschel's theory of earthquakes and volcanic phenomena, to which Mr. Hunt has given a wider extension, connecting it with Mr. Babbage's speculations on the result of the rising of the isothermal lines in the earth's crust, consequent upon the accumulation of sediments. The first result of this heat would, as Mr. Babbage has shown, produce expansion and elevation; but when metamorphism takes place, the contraction attendant upon the conversion of the sediments into the denser silicates, such as chloritoid pyroxene, garnet, epidote staurotide, and chiastolite, must produce an effect directly opposite. In this way Mr. Hunt conceives that while the earth's nucleus may be a solid, although incandescent mass of anhydrous silicates, we may suppose that the inferior strata, which are undergoing metamorphism and igneo-aqueous fusion, agreeable to the views of Poulett Scrope, Herschel, Scheerer, and Sorby, are contracting in such a manner, that we may possibly admit with Elie de Beaumont a shrinking of the fluid mass beneath, which will explain the great plications of the earth's crust, and thus reconcile this theory with the view of a solid nucleus. At the same time he is inclined to refer the great movements of elevation and subsidence, for the most part, to what Herschel has described as "the disturbance of the equilibrium of pressure" consequent upon the transfer of sediments, while the yielding mass reposes upon a mass of matter partly solid and partly liquid.

These views will be found in the 'Reports of the Geological Survey of Canada for 1857 and 1858,' where the experiments upon gypsum and magnesian rocks are given in detail. Also in a memoir published in the 'Quarterly Journal of the Geological Society' for Nov. 1859.

On the Igneous Rocks interstratified with the Carboniferous Limestones of the Basin of Limerick. By J. BEETE JUKES, *M.A., F.R.S.*

The author called attention to some of the lately published sheets of the 'Geological Survey of Ireland,' including this district, and stated that the ground had been surveyed by Messrs. Kinahan, Foot, O'Kelly, and Wynne.

He gave a brief sketch of the physical structure of the country around Limerick, and then proceeded to describe its igneous rocks. These are of two kinds, trap and trappean ash. The trap varies greatly in texture and aspect, more perhaps than in mineral composition. The trappean ash (or tuff) is the result of the mechanical erosion of the igneous rock, either during the time of its eruption or immediately after, and before it was buried under other aqueous rocks. It consists of grains or fragments of trappean material, varying from the finest powder to a coarse conglomerate, with blocks several inches in diameter, and often contains large and small fragments of limestone, and sometimes of other matters.

It is perfectly stratified, lying in regular beds, interstratified both with the limestone and with the trap, and blends, almost insensibly, sometimes into one, and sometimes into the other rock.

In the centre of the district, about Ballybrood, is a small hill of the lower coal-measure shales, resting upon the upper limestone on one side, and on trap on the other. This trap attains a thickness of 800 or 1000 feet, and is chiefly contemporaneous bedded trap, but has some intrusive parts, which cut like dykes into the coal-measures. It rests on a bed of ash, and at its eastern end, at Nicker Hill, near Pallas, the most curious and complicated interstratifications of limestone, ash, and trap may be distinctly observed.

Beneath this upper trap comes a regular band of upper limestone, 600 or 800 feet thick, surrounding the trap and coal-measures on all sides, and forming an oval basin.

From underneath this another great belt of trap and ash crops out, forming a corresponding outer basin, the dimensions of which are about 12 miles from E. to W., and 6 miles from N. to S.

The lower limestone rises from underneath this, and undulates for some miles over the adjacent country. Towards the N.W. some of these undulations are sufficiently great to bring the upper limestone in again, underneath the present surface of the ground, and with that large parts of the lower trap and ash. There are thus formed three considerable detached outlying basins of trap and ash, one round Cahernarry and Roxborough, another about the eastern side of the city of Limerick, and a third round Carrigagunnil. There are also one or two small exhibitions of similar rocks towards the north, apparently on a rather lower horizon.

The above igneous rocks are all bedded and interstratified with the limestones, except in a few places, where they seem rather to occur as small intrusive dykes, cutting through the other traps as well as the aqueous rocks.

In many places the bedded traps become quite vesicular and scoriaceous, the vesicles being often filled with carbonate of lime and other minerals, and thus forming an amygdaloid.

In some places these vesicular parts occur as irregular bands intermediate between bands of solid, compact, or even crystalline trap, precisely resembling the figures given by Sir C. Lyell of the junctions of different flows of lava on Mount Etna.

There are, however, six other detached masses of igneous rock, five on the south and one on the north of the basin above spoken of, which are clearly intrusive masses rising up through the limestone, and not now connected with any overlying contemporaneous sheets of trap. It is probable that these mark the sites of the volcanic foci or funnels, through which some of the sheets of trap flowed to the then surface, such sheets, with the upper limestone including them, having been long ago removed by denudation. It is also probable that similar small detached foci or funnels lie still concealed beneath the areas occupied by the contemporaneous traps and ashes.

One of these detached masses, called Knock Dirk (not the hill which is called merely Dirk), is a true syenite, having crystalline particles of quartz mingled with felspar and hornblende.

It is difficult to give any precise name to the rock comprising the other masses. Some of the traps, both intrusive and contemporaneous, would be commonly called felspar porphyry, others greenstone, and others basalt. When the felspar porphyry loses its distinct crystals of felpar, it might perhaps be called felstone. Felstone, however, as understood by the author, means a rock composed of a trisilicated felspar, mingled with an overplus of silica in a state of paste; and it seems difficult to suppose that silicated rocks proceeding in a molten condition through and over such a basic substance as the carboniferous limestone, should still contain any uncombined silica, except in the heart of a large mass like Knock Dirk. It would seem, therefore, advisable to apply some other name, such as aphanite, for instance, to the compact felspathic rocks above spoken of. In the absence of precise chemical analysis, which the author regretted that he had been unable hitherto to procure, it had seemed better to speak of all the igneous rocks collectively under the vague but sufficiently intelligible designation of trap.

Mr. Jukes also stated, that he was much struck with the very great resemblance between these trappean ashes and some of the traps, and those which he recollected to have observed in the volcanic islands in Torres Straits, where small detached volcanoes have broken through the coral reefs, and formed rudely conical accumulations of stratified ashes containing lumps of coral limestone together with flows of hornblendic lava. It is probable that beneath the sea-level sheets of such lava and volcanic ash lie interstratified with the coral limestone. Certainly, if Torres Straits were depressed, and these islands exposed to the breakers, horizontal beds of the ash and volcanic conglomerates would be derived from them, and spread over the surface of the coral reefs.

On the Tynedale Coal-field and the Whin-sill of Cumberland and Northumberland. By J. A. KNIPE.

The author points out the interesting fact of the true Newcastle coal being worked, and that most successfully, at a distance of about 40 miles west of the Great Northumberland and Durham coal-fields at the locality named. The history of this and an adjoining coal-field, called the Stublick, are both similar, viz. the strata are thrown down many hundred feet by the prolongation of the 90 *Fathom Fault*, which is well known and may be well observed on the Northumberland coast at Cullercotes. The principal shaft sunk on this outlying coal-field, on the line of railway from Haltwhistle to Aldstone Moor, is named the "King Pit," Midgeholm Colliery. The depth of the shaft is 506 feet 6 inches; there are five workable seams of coal, the aggregate thickness of which is 23 feet.

The Great Whin-sill, or interstratified trap, may be traced, more or less, for many score miles in the counties of Cumberland and Northumberland, to its termination on the coast of the German Ocean, at Dunstanburgh Castle. At *Wall Town*, situated on *the old Roman Road*, north by west from Haltwhistle, a town and station on the Newcastle and Carlisle Railway, about 2½ miles, the Whin-sill assumes a very bold bluff appearance, after emerging from the superincumbent limestone rock. In places it has a columnar structure, but has now much of its mural appearance changed by trees growing amongst the ruin and debris of the rocky structure; on the summit there is still a very perfect portion left of the Roman wall. The author described the section through the limestone grit shales, ironstone, and Blenkinsop Mines to the King Pit and Tynedale Fault.

On the Eruption in May 1860, *of the Kötlŭgjá Volcano in Iceland. By* W. LAUDER LINDSAY, *M.D., F.L.S.*

It may interest the Geological Section of the British Association to be informed that an eruption has recently occurred of the Kötlŭgjá volcano, Iceland, from a visit to which island I have just returned. Had time permitted (which it does not) I intended to have drawn up for the British Association a brief account of the chief phenomena of the eruption in question, accompanied by drawings made on the 13th June inst., and a map of the district, and preceded by a summary of the preceding eruptions of the same volcano, which are fourteen in number. I hope at greater leisure to prepare such a notice for some of the journals.

Meanwhile I may concisely state that the volcano in question is situated in the south of Iceland, about twenty miles from the coast, near, but considerably to the east of, the well-known Hekla, which has been quiescent since 1846. Kötlŭgjá is part of a range, fifteen to twenty miles long, of glacier-covered mountains or "Jökuls," which include Eyafjalla, Myrdals and Godalands Jökuls; the average elevation above the sea being between 4000 and 5000 feet. The eruption began on the 8th of May last; it was preceded by earthquakes of a local character; the first indication of its advent being a dark cloud hovering over the summit of the mountain. The usual chief ejecta of Kötlŭgjá, when in a state of eruption, are hot water, pumice, and ashes. On the occasion of the last, or fifteenth eruption, in May last, the most noteworthy phenomenon was the enormous water-flood sent forth, a flood which bore with it pieces of ice so large that they were stranded in the sea (twenty miles distant) at a depth of 20 fathoms. The flames which issued from the crater were on the 12th of May visible in Reykjavik, the capital of Iceland, which is at least eighty miles distant; and on the 16th smoke rose to the height of 24,000 feet, this column of smoke being also visible in Reykjavik. I left Scotland for Iceland on the 8th of June inst., expecting to find Kötlŭgjá still giving forth its fire and pouring out its floods of water. On the 13th we sailed close to the south coast of Iceland from Portland's Hak westward, the weather being beautiful and our view of Myrdals-Jökul and the neighbouring Jökuls excellent: but all was quiet; not a vestige of smoke even was to be seen. Touching at the Westmanna Islands, we were informed that the Kötlŭgjá eruption had ceased a few days previously, having done comparatively little mischief to the farms in its vicinity.

[Details of the eruptions above referred to, as well as an account of the Geology and Topography of Kötlŭgjá, will be found in a paper by the author "On the Eruption in May 1860, of the Kötlŭgjá Volcano, Iceland"—accompanied with a Map "illustrative of the Physical Geography of that part of the South of Iceland in which Kötlŭgjá is situated"—in the 'Edinburgh New Philosophical Journal' for January 1861, p. 6, and pl. 2; and also in his "Contributions to the Natural History of Volcanic Phenomena and Products in Iceland" in the 'Proceedings of the Royal Society of Edinburgh' for 17th December 1860.]—June 1860.

On some Reptilian Foot-prints from the New Red Sandstone, north of Wolverhampton. By the Rev. W. Lister.

The object of this paper is simply to announce the discovery, in a fresh locality, of foot-prints of the *Labyrinthodon*, *Rhynchosaurus*, and of another animal, or animals, with which I am not acquainted. Hitherto, I believe, the remains of the *Labyrinthodon* have only been found in Warwickshire, and the north of Cheshire and its neighbourhood; and the *Rhynchosaurus* in the Grinsel quarry near Shrewsbury*. The foot-prints now discovered have been met with in Staffordshire, in a quarry of the New Red Sandstone, on the very borders of the Red Marl, at a place about six miles north of Wolverhampton, in the parish of Brewood, on the road between "The Stone House" and Somerford. "The Stone House," which is given on the Ordnance Map, is near to Chillington Avenue Gates, and within 200 yards of the quarry. The bed in which the foot-prints occur is about 12 feet from the surface. One of the slabs was so thickly covered with impressions, resembling those of the *Rhynchosaurus*, as to make one feel that the animals which made them must have been very numerous on the spot. These were smaller than most of the others, and I have a strong impression that they were those of *young* animals, they were so uniform in size and form. But unfortunately, the slab, which was from 5 to 6 feet long by from 3 to 4 broad, was removed before I had an opportunity of re-examining it.

The *ripple-mark* is very beautifully preserved on some of the slabs, and so is also the *rain-drops*; while in many cases the amount of sand deposited by each tide is readily discovered by the thickness of its layers, which lie one on the other, and which, by means of the ripple-mark, show also the direction in which the water flowed, or the wind blew, at the time they were deposited. The deposits of two, three, and, in some cases, of even four tides are easily seen.

Some of the foot-prints of the *Labyrinthodon* are 10 inches in length; those of the *Rhynchosaurus* are from 1 to 2 inches.

On the Koh-i-Noor previous to its Cutting.
By the Rev. W. Mitchell *and* Prof. Tennant, *F.G.S.*

On the Contents of Three Square Yards of Triassic Drift.
By C. Moore, *F.G.S.*

The author stated that several years ago he suspected the presence of triassic rocks in the neighbourhood of Frome, from accidentally finding a single block of stone on a roadside heap of carboniferous limestone, containing fish remains of the former age; but that for a long time he was unable to discover it *in situ*. More recently, when examining some carboniferous limestone quarries near the above town, he observed certain fissures which had subsequently been filled up by a drift of a later age. One of these was about a foot in breadth at the top, but increased to 15 feet in breadth at the base of the quarry, 30 feet below, at which point teeth and bones of triassic reptiles and fishes were found. Usually these infillings consisted of a material as dense as the limestone itself, and from which any organic remains could only be extracted with difficulty. In another part of the section he was fortunate enough to find a deposit consisting of a coarse friable sand, containing similar remains. In order that this might receive a more careful examination than could be given to it on the spot, the whole of it, consisting of about 3 tons weight, was carted away to the residence of the author, at Bath, a distance of twenty miles; all of which had passed under his observation, with the following results:—The fish remains, which were the most abundant, were first noticed. Some idea might be formed of their numbers when he stated that of the genus *Acrodus* alone, including two species, he had extracted 45,000 teeth from the three square yards of earth under notice, and that they were even more numerous than these numbers indicated, since he rejected all but the most perfect examples. Teeth of the *Saurichthys* of several species were also abundant; and, next to them, teeth of the *Hybodus*, with occasional spines of the latter genus. Scales of *Gyrolepis* and *Lepidotus* were also numerous, and teeth showing the presence of several other genera of fishes. With the above were found a number of curious bodies, each of which was surmounted by a depressed, enamelled, thorn-like spine or tooth, in some cases with points as sharp as that of a coarse needle; these the author supposed to be spinous scales, belonging to several new species of fish, allied to the *Squaloraia*, and that to the same genus were to be referred a number of hair-like spines, with flattened fluted sides, found in the same deposit. There were also present specimens, hitherto supposed to be teeth, and for which Agassiz had created the genus *Ctenoptychius*, but which he was rather disposed to consider (like those previously referred to) to be the outer scales of a fish allied to the *Squaloraia*. It was remarked that, as the drift must have been transported from some distance, delicate organisms could scarcely have been expected; but, notwithstanding, it contained some most minute fish-jaws and palates, of which the author had, either perfect or otherwise, 130 examples. These were from a quarter to the eighth of an inch in length, and within this small compass he possessed specimens with from thirty to forty teeth; and in one palate he had succeeded in reckoning as many as seventy-four teeth in position; and there were spaces where sixteen more had disappeared, so that in this tiny specimen there were ninety teeth! Of the order Reptilia there were probably eight or nine genera, consisting of detached teeth, scutes, vertebræ, ribs, and articulated bones. Amongst these he had found the flat crushing teeth of the *Placodus*; a discovery of interest, for hitherto this reptile had only been found in the muschelkalk of Germany,—a zone of rocks hitherto wanting in this country, but which, in its Fauna, was represented by the above reptile. But by far the most important remains in the deposit were indications of the existence of triassic mammalia. Two little teeth of the *Microlestes* had, some years before, been found in Germany, and were the only traces of this high order in beds older than the Stonesfield slate. The author's minute researches had brought to light fifteen molar teeth, either identical with, or allied to, the *Microlestes*, and also five incisor teeth, evidently belonging to more than one species. A very small double-fanged tooth, not unlike the oolitic *Spalacotherium*, proved the presence of another genus and a fragment of a tooth, consisting of a single fang, with a small portion of the crown attached, a third genus, larger in size than the *Microlestes*. Three vertebræ, belonging to an animal smaller than any existing mammal, had also been found. The author inferred that if twenty-five teeth and vertebræ, belonging to three or four genera of Mammalia, were to be found within the space occupied by three square yards of earth, that portion of the globe which was then dry land, and from whence the material was in part derived, was probably inhabited at this early period of its history by many genera of Mammalia, and would serve to encourage a hope that this family might yet be found in beds of even a more remote age.

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* After the reading of the paper, it was stated by Mr. Hull of the Government Survey, that impressions of the *Labyrinthodon* have been discovered in two or three other fresh localities, but they have not, as I understand, been published.—W. L.

Remarks on Fossil Fish from the North Staffordshire Coal Fields.
By WILLIAM MOLYNEUX.

The author of this paper stated that little more than two years ago the fossil fish of the coal-field in question comprised, so far as was then known, a list of eight genera only, and those of a kind most commonly found in other home-representatives of the system. Last year, at Aberdeen, he had the honour, in connexion with Mr. Garner, of exhibiting before this Section a collection of such remains, the generic number of which amounted to upwards of twenty, including some new to science, and others of a rare and interesting order. On the present occasion his principal object was to draw attention to some specimens obtained since the period alluded to. One of these, *Ctenacanthus hybodoides* (Egerton), was in a perfect state of preservation. Another specimen was a lower jaw of Rhizodus, whose long powerful teeth, arranged in pairs, resembled in their curved points *R. incurvus* of the Ohio coal-field; but as there appeared to be doubts of its specific identity, probably it would prove to be a new species. There was also a fragment of a massive jaw of the same genus which presented features of much interest to the ichthyologist.

Of the smaller ganoids exhibited, one represented a new genus, obtained from the deep mine ironstone shale at Longton, at the pit where ironstone was first worked for the purpose of manufacture in North Staffordshire. The specimen measured four inches in length, but was scarcely one inch in its greatest depth immediately behind the head; the form being tapering and elegant. The dorsal fin was placed but half an inch before the bifurcating point of the caudal, and slightly in advance of the anal fin, the rays being strong and articulated. The scales were rhomboidal in form, and profusely ornamented with raised lines, which assumed the character of a series of Gothic arches ranging from the centre of the scale. Some undescribed specimens of Palæoniscus, with many large teeth of Placoid fish, were also exhibited.

The coal-field in question was found to be particularly rich in fish-remains; and although little more than two years had been actively devoted to the subject, the generic list had during that time increased from eight to thirty-three in number, and the author felt sanguine that it would ultimately prove quite as rich in species as the Old Red of Scotland. These remains, it was stated, occur very irregularly; some beds of ironstone in the upper division of the measures contain considerably more than others, but it was only in one instance, that of the new mine, that they were found forming a stratum from one to three inches in thickness. Though anything like perfect specimens were comparatively rare, the fine compact shales of the knowls and deep mine ironstones had lately produced some well-preserved specimens of Palæoniscus and Platysoma.

Notice of a Fossiliferous Deposit near Farnell, in Forfarshire, N.B. By J. Powrie. (*Communicated by* Sir R. Murchison.)

This deposit, which is situated on the south-east bank of the Pow Burn, about half a mile south-west of the Farnell Station of the Scottish North-Eastern Railway, mostly consists of fine greyish argillaceous shales, the lower portion splitting into laminæ nearly as thin as writing-paper, and when first opened of a delicate cream-colour; the upper beds are thicker, and vary from a cream-colour to dark grey: in many places these are considerably stained by the infiltration of iron in solution. The dip is, at an angle of about 12°, in a nearly north-west direction, the strike thus following that of the Great Anticline which runs through Forfarshire, a little to the south-east, in a direction of from north-east to south-west nearly.

This deposit rests conformably on a thick-bedded coarse dark red sandstone, and varying from 4 to 6 or 7 feet in thickness, is overlaid by coarse broken shales, above which is a considerable thickness of boulder clay and soil. Both from its position and peculiar organic remains, it can at once be recognized as occupying the same position in the Forfarshire formations as the Turin Hill and Carmyllie flagstones. Cropping out on the banks of a small stream, it was first noticed as affording indications of being fossiliferous by the Rev. Henry Brewster of Farnell, and pointed out by him as such to the Rev. Hugh Mitchell, who first discovered that, besides *Parca decipiens* and remains of *Pterygoti*, &c., it contained small fishes in a state of wonderful preservation; these being, with the exception of *Cephalaspis* and a few very imperfect ichthyolites, the first fishes found in the Forfarshire sandstones: a paper was read, and a selection of these exhibited by Mr. Mitchell at the Meeting of the British Association held at Aberdeen last August (1859). Indisposition has prevented him continuing to aid in these explorations.

The Earl of Southesk, on whose estates this deposit is situated, has lately most liberally opened up this deposit, and placed the examination of its contents under the superintendence of Mr. Brewster and myself: already a considerable portion has been carefully looked over, and has yielded to our researches some most interesting remains: these lie scattered through the whole deposit, but in the upper and coarser beds are for the most part both badly preserved and very fragmentary; in the lower fissile portions they are more perfect, and the state of preservation is generally very fine: no painting could equal the beautiful appearance some of the smaller fishes exhibit when the little slab in which they have been entombed is first opened up, and still damp. From the fragile nature of the matrix, great care is required in splitting it up; and in afterwards fitting up the specimens for preservation they are exceedingly apt to be destroyed.

The *Parca decipiens* is the most abundant organism found; finely sculptured fragments of *Pterygotus Anglicus* and other *Pterygoti* are by no means uncommon; and one or two varieties of as yet unnamed *Eurypteridæ* have been found, and are now in the collections of Mr. Brewster and Mr. Mitchell. But by far the most interesting feature of this deposit is the comparative abundance of small-sized fishes not found elsewhere in Forfarshire; although *Cephalaspis* is frequently found in other localities along with *Pterygotus*, as yet not a fragment of this fish has been disinterred. All the fishes I have as yet examined, in a state of preservation sufficient for identification, belong to the family *Acanthodii*, and, in so far as I am able to ascertain, to the genera *Acanthodes* and *Diplacanthus*. Of the latter genus (*Diplacanthus*), two, if not more, very distinct species have, up to this time, been found; unfortunately these are very rarely entire, the deposit being a good deal fractured and faulted; although the largest of the *Diplacanthus* yet found does not seem to have been over 6 inches in length, only one nearly complete fish of that genus has as yet turned up; the other specimens show merely portions of the body, tail, &c. Of *Acanthodes*, the fishes, being small, are generally much more entire: of this genus I can only discern one species, and this, although provisionally named at the Aberdeen Meeting "*Acanthodes antiquus*," in no way differs, in so far as I can see, from the specimens of *Acanthodes pusillus* I have been able to procure for comparison (these, however, have all been very imperfect), further than the condition of the sediment in which they had been laid down, and similar natural causes might readily explain.

Although by no means prepared to assert the positive specific identity of the Farnell fishes with those of the same genera found in Cromarty, Morayshire, &c., yet their general resemblance to these fishes found in our more northern deposits, in my opinion, strongly points to the probability of our Forfarshire flagstones belonging to an epoch more nearly approximating in geological time to the fish-beds of the northern counties than has as yet been generally thought likely.

Besides these, some very imperfect remains of fishes, evidently belonging to other families, have been found; it is to be hoped that further explorations may throw some additional light on the nature of these fragments (see p. 78).

Sir R. I. MURCHISON exhibited the New Geological Map of the Vicinity of Oxford.

On the Geology of the Vicinity of Oxford.
By Professor PHILLIPS, *M.A., F.R.S.*

On some New Facts in relation to the Section of the Cliff at Mundesley, Norfolk. By JOSEPH PRESTWICH, *F.R.S. &c.*

The object of the author was to correct an opinion which prevailed regarding the superposition of the freshwater deposit at Mundesley. In the interesting sections of the Norfolk coast, given by Sir C. Lyell in the 'Philosophical Magazine' for May 1840, the freshwater beds of Mundesley are represented as intercalated in the Boulder Clay. The wearing away of the cliff since that period has exposed a clearer section, from which it appears to the author that there is no intercalation of the beds; but that the freshwater beds overlie the Boulder Clay, and that they are newer than any portion of the cliff except a bed of the gravel which passes over them. They lie in a hollow worn through the upper beds and the Boulder Clay down to the sands beneath, and they are clearly separated from all these older beds by another and underlying bed of gravel.

The author further noticed that the lower sands and gravels under the Boulder clay contained a layer of marine shells in a perfect state of preservation, consisting of *Mytilus edulis* (some with *Balani* attached) and *Littorina littoralis*, and traces of others. Again, below this is a seam of dark clay containing freshwater shells, chiefly the *Pisidium amnicum*, and a *Unio*, while a short distance lower is the well-known Forest bed with its elephant and other mammalian remains. He concludes by calling attention to the Mundesley deposit as being probably synchronous with the flint-implement bearing deposit of Hoxne.

On Slickensides. *By* J. PRICE.

On the Chronological and Geographical Distribution of the Devonian Fossils of Devon and Cornwall. *By* WILLIAM PENGELLY, *F.G.S.*

The limestones, slates, and associated sandstones of North and South Devon and Cornwall have, as is well known, caused much perplexity as to their real place in the chronological series of the geologist. Thanks, however, to the labours of Professor Sedgwick, Sir R. I. Murchison, Mr. Lonsdale and others, the problem is now generally admitted to be solved; the rocks in question are the equivalents of the Old Red Sandstones of Scotland and elsewhere; they belong to what is known as the *Devonian* age of the world.

Some little difficulty, however, exists—or rather once existed—in the way of the full and unqualified acceptance of this decision. The rocks of Devonshire are crowded with the remains of invertebrate animals, especially sponges, corals, and shells; whilst the supposed contemporary deposits of Scotland and the adjacent isles are so rich in fossil fish, that, in the language of the late Hugh Miller, "Orkney, were the trade once opened up, could supply with ichthyolites, by the ton and the shipload, the museums of the world*;" but the fossils characteristic of either of these districts are not found in the other. Scotland does not yield the mollusks and zoophytes of Devonshire, nor is there recorded in the latter district more than the faintest trace of the ichthyolitic wealth of the North.

Though this fact may still have difficulties connected with it, they have ceased to be chronological; for Sir R. I. Murchison tells us that "The same fossil fishes, of species well known in the middle and upper portions of the Old Red of Scotland, and which in large tracts of Russia lie alone in sandstone, are in many other places found intermixed, in the same bed, with those shells that characterize the group in its slaty and calcareous form in Devonshire, the Rhenish country, and the Boulonnais." "The fact of this intermixture completely puts an end to all dispute respecting the identification of the central and upper masses of the Old Red of Scotland with the calcareous deposits of Devonshire and the Eifel†."

Professor Sedgwick has proposed the following threefold division of the Devonian rocks of Devon and Cornwall:—

"The first and oldest of these groups may be conveniently called the *Plymouth group*, using these words in an extended sense, so as to include all the limestones of South Devon and the red sandstones superior to the Plymouth limestones. The equivalent to this group in North Devon includes, I think, the Ilfracombe and Linton limestones as well as the red sandstones of the north coast.

"The second group includes the slates expanded from Dartmouth to the metamorphic group of Start Point and Bolt Head, and is, so far as I know, without fossils: it may be called the Dartmouth group, and its equivalent in North Devon is found in the slates of Morte Bay, which end with beds of purple and greenish sand-rock and coarse greywacke. It ranges nearly east and west across the county.

"The third group is not, I think, found in South Devon; but in North Devon it is well-defined, commencing on a base-line of sandstone beds which range nearly east and west from Baggy Point (on the western coast) to Marwood (which is a few miles north of Barnstaple), and thence towards the eastern side of the county. This group is continued in ascending order to the slates on the north shore of Barnstaple Bay; but its very highest beds are seen on the south shore of the bay, dipping under the base of the culm-measures.

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* Footprints of the Creator, p. 2.

† Siluria, Third Edition, p. 382.

"The equivalent of this third and highest Devonian group is found to the south of the great culm-trough in a group, near the top of which appear the limestone bands and fossiliferous slates of Petherwin. It may be called the Barnstaple or Petherwin group*."

Professor Sedgwick recognizes the Plymouth group in the slates of Looe, Polperro, and Fowey in Cornwall †.

Accepting, at least provisionally, these divisions, we have, when considered chronologically as well as geographically, what, as a matter of convenience, may be called five fossiliferous areas; namely, a deposit of the age of the Plymouth group in each of the districts, South Devon, North Devon, and Cornwall; and one of the Barnstaple age in each of the two latter. To avoid undesirable repetition, they will be spoken of throughout this paper as Lower South Devon, Lower North Devon, Lower Cornwall, Upper North Devon, and Upper Cornwall. The terms "Lower" and "Upper" are to be understood as applied relatively only to the rocks of Devon and Cornwall, and not as embodying or implying any opinion respecting the co-ordination of these rocks with deposits of the Devonian age elsewhere.

Had existing materials warranted it, it would have been desirable to have made a farther division, namely, one having reference to the mineral character of the deposits, as well as to time and place; for it is certain, as might have been expected, that, in the same area, some fossils are peculiar to the argillaceous beds, and others are found only in the calcareous strata; thus, for example, I learn from Mr. Godwin-Austen that he has found the remarkable coral *Pleurodictyum problematicum* in the slates, but not in the limestones, at Ogwell in South Devon. My own experience is in harmony with this; the same fossil occurs in the slates at Torquay and, in great abundance, at and near Looe in Cornwall; but not in limestone anywhere. At present, however, it would be premature to attempt a division of this kind.

The object contemplated in the present paper is to give some account of the ancient population of the five areas, especially with reference to their distribution, so far as it was known when the Census was last taken.

Amongst the things which have recently drawn my attention to this subject may be mentioned the following passage in the address of Professor Phillips as President of the Geological Society of London. "Only a small proportion of the fossils of North Devon occur in South Devon ‡." And also the following statement by Professor Haughton:—"I do not believe in the lapse of a long interval of time between the Silurian and Carboniferous deposits, in fact in a Devonian period.

"The same blending of corals has been found in Ireland, the Bas Boulonnais, and in Devonshire, where Silurian and Carboniferous forms are of common occurrence in the same localities §."

It should be remembered that the statement with which we have here to deal is that the "blending of *corals*" (the word is not *fossils*) "of Silurian and Carboniferous forms is of common occurrence in Devonshire."

I have consulted such registers as I have been able to command, and have thrown so much of their contents as bear on the questions before us into the following tabular form, for which, of course, no higher value is claimed than attaches to the original documents.

The materials have been in a great degree derived from Professor Morris's 'Catalogue of Fossils.'

Every geologist must, of course, be aware of the numerous and elaborate Tables which Professor Phillips has introduced in his 'Palæozoic Fossils of Devon and Cornwall,' when discussing subjects akin to those at present under consideration. In the preparation of this paper the author has in no way made use of the valuable data these Tables contain.

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[*] Quarterly Journ. Geol. Soc. vol. viii. p. 3.

[†] Ibid. p. 14.

[‡] Quarterly Journ. Geol. Soc. vol. xvi. p. xl.

[§] Voyage of the 'Fox' in Arctic Seas, Appendix, No. IV. p. 387.

TABLE I. Showing the *Absolute* Distribution, in Time and Space, of the Devonian Fossils of Devon and Cornwall.

	Totals.			Peculiar to					Common to										Totals.					Common to					
	Families.	Genera.	Species.	L. S. D.	L. N. D.	L. C.	U. N. D.	U. C.	L. S. D., L. N. D.	L. S. D., L. C.	L. S. D., L. N. D., L. C.	L. S. D., L. C., U. N. D.	L. S. D., U. N. D.	L. S. D., U. C.	L. S. D., U. N. D., U. C.	L. S. D., L. C., U. N. D., U. C.	L. N. D., U. N. D.	U. N. D., U. C.	L. S. D.	L. N. D.	L. C.	U. N. D.	U. C.	Eu.	Eu. Am.	Am.	Eu. Am. Au.	Silurian.	Carboniferous.
Amorphozoa	2	4	9	7	...	1	...	...	...	1	...	...	...	...	...	...	...	...	8	...	2	...	...	1	...	...	...	...	...
Zoophyta	6	20	49	40	1	1	...	...	1	2	1	...	...	2	...	1	...	...	47	3	5	1	3	18	4	1	1	3	...
Echinodermata	3	6	15	7	...	1	6	1	...	...	...	...	...	...	...	...	...	...	7	...	1	6	1	2	...	...	...	...	6
Crustacea	7	8	11	7	...	...	...	2	...	1	...	1	...	...	...	...	...	...	9	...	2	1	2	1	...	...	...	...	1
Bryozoa	3	7	11	6	...	...	2	1	1	...	...	...	...	...	...	...	...	1	7	1	...	3	3	1	...	...	...	...	6
Brachiopoda	7	16	108	58	3	3	14	7	5	1	...	...	3	3	3	...	1	7	73	9	4	28	20	20	1	...	...	2	24
Lamellibranchiata	9	17	49	15	1	...	16	11	...	...	...	...	2	1	...	...	1	2	18	2	...	21	14	7	...	...	...	2	4
Gasteropoda	9	14	47	31	...	1	6	3	...	...	...	...	...	2	1	...	...	3	34	...	1	10	9	6	...	...	...	...	10
Cephalopoda	3	5	48	20	...	...	6	18	...	...	...	...	1	2	...	...	...	1	23	...	...	8	21	5	...	...	...	1	7
	49	97	347	191	5	7	50	43	7	5	1	1	6	10	4	1	2	14	226	15	15	78	73	61	5	1	1	8	58
				296					51															68				66	
				347																									

We learn from the three left-hand columns of figures headed "Totals" in the

Table, that, taken together, the five areas have yielded 347 species of fossils belonging to 97 genera and 49 families, of 9 classes of animals; namely, three classes of the subkingdom Radiata, one of Articulata, and five of Mollusca; hence 15 of the 24 classes into which the existing animal kingdom is commonly divided are totally unrepresented in the series, as is the entire vegetable kingdom also.

It is scarcely necessary to remark that the fossils of Devon and Cornwall do not fully represent the organisms of the Devonian age, as six other classes—Pisces, Pteropoda, Cirripedia, and Annelida amongst animals, and Cellulares and Monocotyledones amongst plants—have been found in rocks of this age elsewhere; and of these the last and first two have been met with in British localities.

The most important class numerically is Brachiopoda, to which 108 species belong; that is 31 per cent. of the entire series. The families and genera of Cephalopoda are richer in species than those of any other class, averaging 16 for each family and 10 for each genus.

The most striking fact in this connexion, is the abundance of Brachiopoda and Cephalopoda, and the paucity of Lamellibranchiate and Gasteropod species, as compared with the numerical rank of the same classes in the existing British fauna; this will, perhaps, be most strikingly exhibited by the following Table:—

Table II.

	Devonian Mollusca of Devon and Cornwall.	Existing British Mollusca.
Bryozoa	42	72
Brachiopoda	410·5	15·5
Lamellibranchiata	186	359·5
Gasteropoda	179·	521·5
Cephalopoda	182·5	31·5
	1000	1000

which has been thus computed; in the left-hand column the aggregate number of the species of fossil Mollusca found in Devon and Cornwall has been put=1000, and the numbers belonging to each class equated to this; the right-hand column has been formed on the same principle, and is based on the data given by Forbes and Hanley in their 'History of British Mollusca.'

It appears then that within existing British seas, the Lamellibranchiates are about twenty-four times more numerous, specifically, than the Brachiopods, whilst within what may be called the same area, the latter were to the former during the Devonian period somewhat more than as 2 to 1; that is, they were then 50 times more abundant than at present in comparison with the other great class of Acephala. In like manner it is seen that, relatively to the Gasteropoda, the Cephalopoda were, in this early age of our planet, seventeen times more numerous than now. It may be added that, within the district under notice, the registered species of Devonian Brachiopoda and Cephalopoda absolutely, and in a high ratio, exceed those belonging to the same classes within existing British seas.

The five columns of Table I. headed "Peculiar to," and distinguished from one another by the initials of the five areas, show the number of fossil species which, so far as England is concerned, are peculiar to each; from which it appears that 296 species are peculiar to one or other of them, leaving no more than 51 distributed amongst them. Lower South Devon monopolizes no fewer than 191 species in this way, whilst Lower North Devon is equally remarkable for its fossil poverty.

Five areas, taken two, three, four, and five together, are capable of being formed into twenty-six different combinations. Not a single species is common to the five areas, and only one, *Cyathophyllum celticum*, is found in each of four of them. The well-known coral *Favosites cervicornis* is the only fossil found in each of the three contemporary deposits of Lower North and South Devon and Cornwall. Of two areas only, Upper North Devon and Upper Cornwall have the greatest number—fourteen—in common.*

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* See in Table I. the ten columns headed "Common to," and distinguished by combinations of initials of two or more areas.

It must be understood that any one of the ten columns just noticed shows, not the total number of species common to the areas the initials of which stand at its head, but simply the number at once common and restricted to them collectively; thus the second of these columns, headed L. S. D., L. C., shows that five species are common and restricted to Lower South Devon and Lower Cornwall; but in the third column we find one species common to them and also to Lower North Devon, in the fourth one common to them and to Upper North Devon, and in the eighth one found in each of them and also in Upper North Devon and Upper Cornwall; hence there are eight species common to the two areas instanced, five being restricted to them collectively and three not. The same explanation applies to the other areas. Hence the total number of species found in any area will be ascertained by adding the figures in all the columns marked "Peculiar to" and "Common to" at the head of which the initials of the area are found; thus, for example, a total of 47 species of *Zoophyta* occurs in Lower South Devon, of which 40 are not found elsewhere in Devon and Cornwall. Moreover, as the column marked "Species" shows that the two counties have yielded a total of 49 species belonging to this class, it is evident that two of this total number have not been met with in Lower South Devon. And so on for the other classes and areas, as is shown in the five columns headed "Totals" and distinguished by the initials of the areas.

Of the 347 species, 67 are met with in various parts of Continental Europe, and 7 in North America; 6 of the latter being included in the European 67, and one of the 6 is also found in New South Wales; thus making a total of 68 common to Devon and Cornwall and to districts beyond the British Isles*.

Comparatively few of the Devonian fossils of the two counties appear to have been derived from the Silurian fauna; eight species only are referable to that earlier period†. Amongst these are the three corals, *Favosites fibrosa*, *Emmonsia hemisphærica*, and *Chonophyllum perfoliatum*. The first has been found in Lower Silurian rocks at Llandovery; in the upper deposits of the same system in various parts of the typical Silurian country, in eight counties of Ireland, in Russia, and in three North American localities; during the Devonian era it existed in several parts of Devonshire, in France, and in Germany. The second, *Emmonsia hemisphærica*, dates its origin in Upper Silurian times, when it seems to have been confined to the area of modern North America, ranging from the State of Ohio to Tennessee; having outlived the Silurian period, it sent colonies to Spain and Britain and greatly extended its range in America.

Chonophyllum perfoliatum differs from the two former in having always lived within narrow geographical limits; it occurs in Upper Silurian beds at Wenlock, and in Devonian in one quarry near Newton in Devonshire; but its appearance is not recorded elsewhere.

The wide geographical range of the first two would seem to imply hardy plastic constitutions, fitting them for distant travel, and existence under varied circumstances; there is, therefore, nothing very surprising in their extended vertical range; it is, perhaps, worthy of remark, that the second seems to have disappeared at the very zenith of its widely extended power.

The very limited distribution, in space, of the last of the trio would scarcely suggest the thought that such an organism would be likely to be capable of enduring physical and thermal changes such as, there are reasons for believing, considerable lapses of time have always introduced into any given area; changes probably similar to those which an organism would experience in passing to a distant locality in any one and the same period.

On the other hand, the well-known fossil coral *Favosites Goldfussi* occurs in Devonian rocks in Devonshire, at Nehou and Visé in France, at Millar in Spain, in the Oural, in the States of Ohio and Kentucky in North America, and in New South Wales. It seems to have successfully struggled with the varying conditions of change of place, and might have been expected to be equally capable of contending with such as depend on lapses of time; nevertheless, the facts do not harmonise with such inferences; *Chonophyllum perfoliatum* formed part of the Silurian and Devonian faunas, but was confined to the British area; *Favosites Goldfussi* was at home in every part of the world, yet it commenced and terminated its career within the Devonian period.

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* See in Table I. the columns headed Eu. (Continental Europe), Eu. Am. (Europe and America), Am. (America), Eu. Am. Au. (Europe, America, and Australia).

† See in Table I. the column headed "Silurian."

The rocks of Devon and Cornwall have 58 species of fossils in common with those of the Carboniferous group*, but no corals or sponges amongst them; so that it cannot be said that "there is a blending of Silurian and Carboniferous corals in Devonshire," whatever there may be elsewhere; for though, as has been stated, three Silurian corals have been found, not one referable to the Carboniferous fauna has been exhumed there†.

The species which thus passed from the Devonian into the Carboniferous period are found in the three principal fossiliferous deposits of Devon and Cornwall, as exhibited in the following Table:—

TABLE III.

	Totals.	L. S. D.	U. N. D.	U. C.
Echinodermata	6	3	2	1
Crustacea	1	1	...	...
Bryozoa	6	3	2	2
Brachiopoda	24	15	9	7
Lamellibranchiata	4	2	...	2
Gasteropoda	10	6	3	3
Cephalopoda	7	4	2	3
	58	34	18	18

The populations of the three areas seem to have been thus composed:—

South Devon:—6 Silurians + 220 new species (*i. e.* Lower Devonian) = a total of 226, of which 34 passed into the Carboniferous.

Barnstaple:—1 Silurian + 13 Lower Devonians + 64 new (Upper Devonians) = a total of 78, of which 18 passed into the Carboniferous.

Petherwin:—1 Silurian + 15 Lower Devonians + 57 new (Upper Devonians) = a total of 73, of which 18 passed over to the Carboniferous.

Of the "new forms" in the Barnstaple and Petherwin areas (64 and 57 respectively) 14 are common.

It is perhaps worthy of remark that the five areas have a smaller number of organic forms in common—closely connected as they are both in time and space—than with Devonian deposits in Continental Europe and elsewhere beyond the British Isles, or with the Carboniferous rocks of Ireland and Central and Northern England.

Table I., to which attention has so frequently been directed, represents, so far as is at present known, the *absolute* distribution of the fossils in the two counties in which they occur; but, for purposes of geological chronology, it is probably of greater importance to ascertain their *relative* distribution; this is shown in Table IV., which has been calculated from Table I. thus: the total number of species in each class is put = 1000, and the figures in the other columns equated to this.

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* See in Table I. the column headed "Carboniferous."

† See 'Monograph of British Fossil Corals,' by Messrs. Edwards and Haime, pp. 150 and 212.

TABLE IV. Showing the *Relative* Distribution, in Time and Space, of the Devonian Fossils of Devon and Cornwall.

	Peculiar to					Common to										Totals.					Common to					
	L. S. D.	L. N. D.	L. C.	U. N. D.	U. C.	L. S. D., L. N. D.	L. S. D., L. C.	L. S. D., L. N. D., L. C.	L. S. D., L. C., U. N. D.	L. S. D., U. N. D.	L. S. D., U. C.	L. S. D., U. N. D., U. C.	L. S. D., L. C., U. N. D., U. C.	L. N. D., U. N. D.	U. N. D., U. C.	L. S. D.	L. N. D.	L. C.	U. N. D.	U. C.	Eu.	Eu. Am.	Am.	Eu. Am. Au.	Silurian.	Carboniferous.
Amorphozoa	778	...	111	...	...	...	111	...	...	...	...	...	...	...	...	889	...	222	...	...	111	...	...	...	...	...
Zoophyta	818	20	20	...	...	20	41	20	...	...	41	...	20	...	...	960	61	102	20	61	367	82	20	20	61	...
Echinodermata	467	...	67	400	67	...	...	...	...	...	...	...	...	...	...	467	...	67	400	67	133	...	...	...	...	400
Crustacea	636	...	...	...	182	...	91	...	91	...	...	...	...	...	...	818	...	182	91	182	91	...	...	...	...	91
Bryozoa	545	...	...	182	91	91	...	...	...	...	...	...	...	...	91	636	91	...	273	273	91	...	...	...	...	545
Brachiopoda	537	28	28	130	65	46	9	...	...	28	28	28	...	9	65	676	83	37	259	185	185	9	...	...	19	222
Lamellibranchiata	306	20	...	327	224	...	...	...	...	41	20	...	...	20	41	367	41	...	429	286	143	...	...	...	41	82
Gasteropoda	660	...	21	128	64	...	...	...	...	...	43	21	...	...	64	723	...	21	213	191	128	...	...	...	...	213
Cephalopoda	417	...	...	125	375	...	...	...	...	21	42	...	...	...	21	479	...	...	167	438	104	...	...	...	21	146

Each area is marked by some class being relatively most abundant in it, as is exhibited below, thus[*]:—

L. S. D.	L. N. D.	L. C.	U. N. D.	U. C.
Zoophyta.	Bryozoa.	Amorphozoa.	Lamellibranchiata.	Cephalopoda.

When ranged, in descending order, so as to show, relatively, the migration of their species from the Devonian to the Carboniferous era, the classes stand thus: Bryozoa, Echinodermata, Brachiopoda, Gasteropoda, Cephalopoda, Crustacea, Lamellibranchiata[†].

The distribution of the genera is just as marked as that of the species; 92, out of the total 97, are found in Lower South Devon, and of these 45 are, in Britain, peculiar to it. Every genus of the classes Zoophyta and Brachiopoda occurs in it; the genera thus limited, however, are usually poor; 33 of the 45 contain each but a single Devonian species. The richest genus not found elsewhere is Acervularia, a group of corals belonging to the great Palæozoic family Cyathophyllidæ; it contains 7 species, all peculiar to this area. One of the richest genera in the entire series is *Clymenia*, belonging to the class Cephalopoda; of this genus 11 species are found at South Petherwin, and not one is met with elsewhere in Britain. The genus *Cyrtoceras*, with the single exception of *C. rusticum* (probably a synonym for *Orthoceras arcuatum*), is restricted to Lower South Devon, where it is represented by 12 species.

The chronological range of the Devonian genera of Devon and Cornwall is shown below.

TABLE V.

	Total Devonian Genera.	Peculiar to Devonian.	Common to		
			Devonian, Silurian.	Carboniferous, Devonian, Silurian.	Carboniferous, Devonian.
Amorphozoa	4	3	1	...	...
Zoophyta	20	10	5	3	2
Echinodermata	6	2	...	3	1
Crustacea	8	1	5	...	2
Bryozoa....................	7	...	...	5	2
Brachiopoda..............	16	3	2	8	3
Lamellibranchiata.......	17	2	1	9	5
Gasteropoda	14	2	...	11	1
Cephalopoda	5	1	...	2	2
	97	24	14	41	18

Some of the genera common to the Devonian and Carboniferous eras, are found also in more recent deposits, and even in the existing fauna.

Such appear to be the prominent facts in connexion with the subjects under consideration. What is their interpretation? This is a problem more easily proposed than solved. Are we to believe that our knowledge of the geological record is too imperfect to warrant any important generalizations? Do our museums fully represent the fossilized remains of bygone forms of life? Have all the extinct organisms already in our possession been registered in the published lists? Is the record itself so incomplete as to be altogether incapable of revealing to us the physical and organic history of our planet? Are the notions of biologists respecting specific distinctions sufficiently mature and uniform to warrant a reliance on their decisions? Something must doubtless be conceded on each of these points; still there cannot but be a large outstanding amount of fact incapable of being thus explained away; the problem demands some other solution. Suppose it true that in some cases the organic dissimilarity, which has been described, was due to differences in the mineral character of the ancient sea-bottoms; still when we have two areas like Lower South and North Devon, consisting of contemporary, almost contiguous, and scarcely dissimilar deposits, one rich and the other poor in the variety of its organic remains, having together 233 species yet no more than 8 in common, some other solution is obviously needed.

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[*] See in Table IV. the columns headed "Totals."

[†] See in Table IV. the column headed "Carboniferous."

Was there a terrestrial barrier separating the two areas? Was that which is now Central Devon occupied by dry land, which stretched far both east and west, while the waves of the *Devonian* ocean rolled over the north and south of the county? All the known physical facts are opposed to such a hypothesis. Moreover, 8 species actually did migrate from one area to the other; eight proofs, then, that a passage did exist, unless we suppose that both areas were peopled from some more distant centre or centres of dispersion.

It may be asked, were not these eight the remnants of an earlier (a Silurian) fauna? forms of life whose localization had been determined by an earlier distribution of land and water? Eight Silurian forms do make their appearance amongst the Devonians of Devon and Cornwall; are not these the very eight thus common? Now it so happens that they are not; in fact there is not a single Silurian form in the Lower North Devon series. This hypothesis then fails. Shall we hold with Professor Phillips, that "this unequal diffusion of definite forms of life may often be ascribed to oceanic currents*?" I cannot but think that fewer difficulties attach to this than to any other hypothesis which has been proposed. It simply requires us to suppose that a persistent oceanic stream, flowing through Central Devon, separated the contemporary deposits of the north and south, and formed, by its thermal or other qualities, an all but impenetrable barrier to the marine tribes.

Though, as we have seen, at least so far as Devonshire is concerned, the basis entirely fails on which scepticism respecting the existence of a Devonian period has been founded, namely, that "the blending of Silurian and Carboniferous *corals* is of common occurrence," yet if the word "fossil" be substituted for "coral," a blending of this kind certainly does occur, and doubtless the fact is not without a meaning. Eight species from the older and 58 found in the more modern (a total of 66) meet in Devon. Are they necessarily so many proofs that the rocks in which they were inhumed are not Devonian? It must be borne in mind that there are 281 species that are neither Silurian nor Carboniferous, but of an intermediate character. The palæontological argument then stands thus: there are 66 witnesses supposed to testify that the rocks are not Devonian, and 281 (upwards of 4 to 1) emphatically declare that they are. But the adverse witnesses are by no means agreed amongst themselves; eight of them claim the rocks as Silurian, and fifty-eight as Carboniferous. Is there no way of interpreting their evidence, but that of sacrificing the Devonian system altogether? Are they not so many arguments in favour of the gradual passage of system into system? so many difficulties in the way of a belief in catastrophes? by which I mean convulsions (or call it by any other name) which, from time to time, shook the very life out of the world, causing a series of universal and synchronous depopulations of our planet. May we not regard them as so many tints intermediate, both in quality and in place, between the extreme bands of the rainbow, uniting them into one beautifully graduated chromatic spectrum, so softly blending as to render it impossible to define the exact place of lines of demarcation? which perhaps have not, and never would have been supposed to have, a physical existence, had not observers hastily generalized from the imperfect evidence obtained during a period of colour blindness.

But if the Devonshire rocks were handed over to the Carboniferous system, we should not be quit of the doctrine that some of the forms of one period have, at least in some instances, lived through it into the next; for the opponents of a *Devonian* period not only admit this, but rest their case on the alleged fact that "Silurian and Carboniferous forms are found blended together in Devonshire and elsewhere." When, nearly a quarter of a century ago, Mr. Lonsdale first suggested that the fossils of South Devon, taken as a whole, exhibited a peculiar character intermediate to those of the Silurian and Carboniferous groups, he was perfectly aware that amongst them were forms referable to each of these faunas, yet this did not deter him from making the suggestion, even in the face of a physical difficulty connected with the culmiferous beds of North Devon—subsequently removed by Prof. Sedgwick and Sir R. I. Murchison.

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* Quarterly Journ. Geol. Soc. vol. xvi. p. xl.

And what has been the effect of the recent progress of discovery and nicer discrimination on this question? Has it increased or decreased the evidence in favour of a Devonian period? In 1846 Sir H. De la Beche, discussing this subject, gave a total of 190 species noticed in South Devon which he disposed of thus: 75 Carboniferous forms, 10 Silurian, 8 common to Silurian and Carboniferous, and 97 peculiar to Devonshire*. At present—confining ourselves also to South Devon—the lists give a total of 226, of which 34 are Carboniferous, 6 Silurian, not one common to both, and 186 peculiar to the district; or putting the totals at each period =1000, and equating the separate numbers to this, the figures stand as in the following Table, and show a decided advance Devonianward.

Table VI.

	1846.	1860.
Silurian	53	27
Carboniferous	395	150
Silurian and Carboniferous	42	0
Peculiar	510	823
	1000	1000

Doubtless the fact that the Carboniferous forms so greatly outnumber the Silurian has a meaning. Does not this greater organic affinity betoken a closer chronological connexion with the more recent than the more ancient period? Is it not an intimation that the lowest beds of Devonshire do not constitute the basement of the Devonian system? That the county has an ample development of Upper and Middle, but not of Lower Devonian rocks?"

Hitherto we have accepted the hypothesis that the South Devon rocks are more ancient than the Barnstaple and Petherwin groups, and that the two last are contemporaries. It may perhaps be well before concluding this paper to glance at the bearings of the palæontological evidence at present before us on this point. Putting the entire series of fossils found in each of the three districts=1000 and equating accordingly, the numbers stand as below.

Table VII.

	South Devon.	Petherwin.	Barnstaple.
Silurian	27	14	13
Devonian	823	740	756
Carboniferous	150	246	231
	1000	1000	1000

Whence it seems tolerably safe to infer that neither of the three deposits is Carboniferous or Silurian, but intermediate, having a closer connexion with the former than the latter period, and that South Devon is the most ancient of the three groups; but the evidence is scarcely strong enough to carry any conclusion respecting the relative age of the remaining two; so far as it goes, it amounts to no more than a suggestion that Petherwin is rather more modern than Barnstaple. Be that as it may, the fossils found common to South Devon and each of them must be regarded as contributions from it to them; using the same notation as above, the figures stand—Lower Devonians in Petherwin 205, in Barnstaple 167; and intimate a relative age the reverse of that just suggested, so that the only thing proved is the insufficiency of the evidence to decide the point; unless, indeed, it leaves us where it found us, accepting the hypothesis that the two deposits are strictly of the same age.

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* "Memoirs" of Geological Survey, vol. i. p. 96.

The figures now produced, though they fairly represent our present knowledge, can only be regarded as rough approximations. It is more than probable that whenever the Census is taken again, it will be found necessary to make, perhaps extensive, modifications in the Tables.

On some Phenomena of Metamorphism in Coal in the United States.

By Professor H. D. ROGERS, *LL.D., F.R.S., F.G.S., Glasgow.*

On the Geology of the Neighbourhood of Cambridge and the Fossils of the Upper Greensand.

By the Rev. Professor SEDGWICK, *F.R.S., F.G.S.*

On three undescribed Bone-Caves near Tenby, Pembrokeshire.

By the Rev. GILBERT N. SMITH.

The first of these caves was discovered about twenty years ago in blasting a cliff overhanging the sea at Caldy Island, for the purpose of transporting the mountain limestone of which it is composed to the opposite coast of Devonshire. It had no external opening at that time: the side walls were vertical, or nearly so, the strata standing perpendicular to the plane of the horizon, as they frequently do hereabouts. The cave was formed by a stratum of considerable thickness, having disappeared at that place for some eight or ten yards, being probably of softer materials than that both above and below, supposing the mass to be restored to its natural horizontal position; and this apparently by the action of the sea in earlier periods. Both the walls and the roof have since been removed, so that now no *cave* exists there; but the *floor*, still containing fragments of bone, is covered with the debris of the quarrymen's labours.

While the cave yet remained I obtained from it the usual osseous relics of the cave mammals,—as bones of the *Elephas primigenius*, *Rhinoceros*, *Sus Scrofa*, *Equus*, *Cervus*, *Bos*, *Ursus*, *Hyæna*, *Felis Tigris* or *Leo*, *Lupus*, *Canis Vulpes*, and some smaller Carnivora. Besides these bones, there were the remains of marine fauna—abundance of dorsal spines of some species of ray probably: these varied in length from 1½ inch to 2 inches; and other portions of fish skeletons.

The larger bones showed the same marks of gnawing described in the 'Reliquiæ Diluvianæ' of Buckland. Some of them exhibit down the edges impressions of the teeth of a Rodent, probably a rat. The nearer these bones lay to the surface of the red water-washed loam in which they were imbedded, the lighter they were, and more nearly approaching in every respect the condition of exposed bones of recent existing animals; indeed many on the surface were sheep's bones; but some on high ledges of the cave were in the same ponderous state as those below, which is usually called fossil. At this time geology had not so far progressed as to suggest the possibility of human remains, which therefore, if present, were not observed.

The condition of the cave in general, and the situation of some of the bones in particular, suggested nothing of the probability of this being a den of hyænas, by whom the bones had been conveyed into its recesses, but quite the contrary. Hyænas' bones lay about precisely in the same condition as the rest: the whole seemed to have been forcibly driven into the cavern by the action of water; and some of the bones, particularly a large ulna, 10½ inches in diameter, were wedged firmly into fissures, just as pieces of drift wreck are observed to be on rocky coasts.

It is assumed in the 'Reliquiæ Diluvianæ' that the presence of hyæna's dung in these caves decides this point; but it should be remembered that the hyæna is a bone- rather than a flesh-eating animal, and that consequently the coprolitic balls are exceedingly hard, being composed almost entirely of phosphate of lime; and that they stand the action of water almost, if not altogether, as well as the bones themselves. My impression is that the whole were carried into the cave by water, and that the bones were gnawed before they were deposited there. Moreover, if these Troglodytæ follow the habits of their congeners in this latitude at present, they will be found to seek external, and even distant places for the purpose indicated. Badgers, for instance, resort to the *same* place nightly; and the ground glitters with the elytra of beetles, which at one time of the year constitute their principal food. It is an ill bird that fouls its own nest. The cleanly habits of dogs, too, are well known.

A brief notice will suffice to mark the site of the second cave for future examination. It is on the same coast-line, and about the same sea-level, but further to the eastward. Like the former, its walls have been removed. The floor was covered with bones, which were shovelled into the sea when it was first broken into by the quarrymen.

The particulars of the third cave will at this time be more interesting, perhaps, because with some of the same remains of Carnivora mentioned above, flint-implements, apparently of human workmanship, have been obtained.

This cave is situated on the main land, and has a large open entrance half-way up the cliff, known to the inhabitants by the name of "the Hoyle." I am not aware that it was examined with a definite purpose till about twenty years ago, when Major, afterwards Colonel, Jervis and Major Pugett exhumed two so-called flint celts, and one of metal, which were sent to a museum in London. Lately a more careful examination has been made of the contents of the red loam which constitutes the floor of what may be called the first chamber of the long winding passage of which this cave consists. Teeth of the bear and hyæna were discovered in this deposit, together with a considerable accumulation of sheep, pigs, and other existing animals. Here also are fish-bones, mixed with littoral shells like those of our present sea; among them may be named *Patella*, *Cardium*, *Purpura lapillus*, *Mytilus*, *Littorina littorea*, and *Natica monilifera*. Most of these shells are found also in the *raised beaches* which appear at different heights all round the adjacent coasts.

Of the filling of these caves we have *possibly* some examples in the deep holes which occur in water-courses, over mountain limestone, in the neighbourhood, and which receive the mud and water after every glut of rain, for very many years, without becoming choked or full; but something more in the nature of a flood would really sometimes appear to be necessary to account for some of the phenomena.

On the Selection of a Peculiar Geological Habitat by some of the rarer British Plants. By the Rev. W. S. SYMONDS, *M.A., F.G.S.*

The Rev. Mr. Purchas, who is now engaged on the Botany of Herefordshire, has divided the county of Hereford into twelve districts, and Mr. Symonds has been struck by the apparent selection of a peculiar geological habitat by some of the rarer British plants.

The Snowdonian plants appear to affect the bands of volcanic ash that are interstratified with rocks of Snowdon.

Lychnis viscaria grows in four botanical districts out of five in Great Britain on Greenstone; it grows on Stanner rocks, near Kington, with *Scleranthus perennis*. *Carex montana* is only found on the carboniferous limestone. *Lathyrus Aphaca*, in Worcestershire, affects the Keuper marls and sandstones.

Mr. Symonds asks his brother naturalists especially to observe the flora of *isolated trap rocks*, and do him the favour of forwarding to him the result of their observation.

On the Geological System of the Central Sahara of Algeria.
By the Rev. H. B. TRISTRAM, *M.A., F.L.S. &c.*

The paper, of which a short summary is appended, was compiled from the notes and observations made during a six months' travel in the Sahara. The writer has no pretensions to being a geologist, nor was geology the object of his wanderings.

But as so little is known respecting the characteristics of this portion of North Africa, he has not hesitated to give the result of his observations, in the hope that the attention of more able and scientific naturalists may be directed to so interesting a field.

On leaving the Atlas crest, and descending its southern slopes, we soon come upon the secondary rocks, which are the prevailing formation of the whole country between the Atlas and Laghouat. This district for about 400 miles due south is rocky, and with mountain-ranges running for the most part in parallel lines north-east and south-west. The southern slopes of the Atlas chain rise from a depression which in several parts, especially to the south of Tunis, is many feet below the level of the Mediterranean. From this depression the Sahara is for the most part a system of endless terraces, some of which are only a few miles apart, while others are expanded into plains of from 50 to 100 miles in width, and which, so far as my observations and the information I could gather from native caravans and a trustworthy guide extended, in an unbroken series to within three days' journey of Timbuctoo, when the traveller will probably find himself on the northern watershed of the valley of the Niger.

As we advance, on every stage is written the record of the retiring ocean, which gradually, by the elevation of its southern shores, was driven back and back to the northward, till the last long inlet from the Gulf of Cabes to Tuggurt was drained and evaporated, leaving its traces in the salt plains, and occasional moisture of the Wed R'hir and Chott el Melah—the ancient Lake Tritonis.

There are several singular exceptions to the course of the mountain-ranges above mentioned, which are generally the local causes of the oases.

Thus at Laghouat we find several elliptical basins of diminishing size piled one on another. The lowest and largest rests on the flat surface of the secondary rock, which is the base of the whole system. Several great fissures, which pervade all these superimposed basins, allow the water to percolate. It then rests on the impermeable rock, draining through a very thin stratum of gravel or sand into any depressions, whence it is raised by artesian wells, and creates an oasis.

From the Sebaa Rous to Laghouat, all these ranges appear to belong to the lower chalk formation. Limestone predominates, and forms the ridges of the Sahari, Senalba, and Djellal mountains. It is of saccharoid structure, and of a variable colour, generally greyish white. In many of the plains there is sandstone, sometimes hard, and at other times so soft as to yield to the pressure of the fingers. This sandstone encloses nodules of flint of various colours and semi-transparent. By disaggregation these become detached from the softer medium in which they were imbedded. As the wind sweeps the sand, they form shingly beaches of pebbles, many of them of a pretty chalcedony, which is exported in some quantity to Paris.

The upper deposit of limestone is marked by regular beds of gypsum of vast extent, which are found in every district of the Sahara, but never in the secondary formation of the Atlas region.

South of Laghouat, the furthest French outpost, we came upon a shallow alluvial deposit of the very latest tertiary and diluvian formation. Near the mountains this is often composed of rolled pebbles in a limestone matrix. On the plains it is a white calcareous rock, a sort of crust, very hard at the surface, but soft and friable below, where it is mixed with green or grey clay, and encloses many crystals of gypsum.

The diluvian formation may be traced more or less distinctly, I believe, between all the ranges, even as far north as the Zahrez, near Djelfa.

I was particularly struck by the fact that several of my fossil shells from these superficial deposits proved specifically identical with freshwater tertiary fossils from the region of the Black Sea. May not further research perhaps reveal, that at no very distant geologic epoch a vast chain of freshwater lakes, similar to those of North America at the present day, extended from the plateaux of the western Sahara as far as the neighbourhood of the Caspian?

The basin of the M'zab country further still to the south supplied me only with a few fossils, apparently miocene.

In turning from the M'zab southwards to Waregla, and thence north-east towards Tuggurt and the Gulf of Cabes, the geological system appears to be the same, but with fewer distinct little basins, and with more extensive diluvial deposits.

As far as we could trace them, the basins are generally horizontal up to Biskra in the north, and Gufza in the east, or very slightly inclined, consisting of alternating beds of greensand (?), gypsum, and clay. These beds extend almost without interruption, or with very slight depressions, from latitude thirty-one degrees north to thirty-five degrees north, and from longitude five degrees east to nine degrees east.

The most interesting portion of this district is the Wed R'hir, a long line of depression sloping from the Touareg desert, latitude thirty degrees north, and longitude five degrees east (circiter), with its surface occasionally moistened by salt lakes, but without any springs of fresh water, yet affording at intervals throughout its whole extent a never-failing supply of sweet water, through artesian wells penetrating the upper limestone. An immense population is supported by this Wed R'hir, which is for many days' journey one continuous line of oases, such as El Marier, Tamerna, Tuggurt, Temaçin, and after a further interval, in which its traces are lost, it reappears in the oases of N'Goussa and Waregla, and gradually is lost in the highlands of the south. But it is probable that even here the subterranean course of the water can be traced, and that the Touareg owe their means of subsistence to their knowledge of wells on this line.

The Wed R'hir terminates in the Chott Melr'hir, a depression probably eighty feet below the Mediterranean sea-level and the lowest point of the whole Sahara. This basin extends eastwards to the Chott el Melah (Lake Tritonis), at a greater elevation, but yet scarcely rising to the sea-level, from which it is separated by some thirty miles of sand-hills and rocks.

Proceeding northwards of the Melr'hir, we rapidly lose all traces of the diluvial deposits, and come upon the chalk, chalk-marl, and greensand in regular succession, dipping generally southwards. The three southernmost ridges of the Mons Aures, viz. the Djebel Checha, the Dj. Khaddou, and Dj. Amar, present us with these three stages of the cretaceous group in order.

When we advance to the north of Biskra, the boundary between the Tell and the eastern Sahara, the mountains are composed of masses of nummulite limestone, with bands of gypsum and occasional interruptions of rock-salt, mixed with layers of marl. One of these mountains of rock-salt has been described long since by Dr. Shaw—that of El Outaia.

There are many salt deposits, sometimes masses of isolated rock-salt, perfectly pure, of many hundred yards in circumference, as at Hadjera el Mehl (or Rochers de Sel), more frequently in the form of layers or incrustations on the plains near the Chotts, or beds of evaporated lakes. Some of the isolated rock-salt hills have been suggested to have been eruptions of argillaceous mud, gypsum, and rock-salt across the secondary and tertiary deposits.

In such a country as the Sahara, we cannot expect to find much mineral wealth, beyond the salt, gypsum, and natron. There is a quarry of oxide of manganese in the Djebel Trisgrarine, traces of lignite and carbonized trees at Ain el Ibel, and many hot springs—some pure, others strongly impregnated with chlorine. The temperature of one of these I found to be 125° Fahr., of others from 75° to 95° Fahr. In one of the latter were swarms of a little fish, *Cyprinodon dispar*, also found in the warm springs of Egypt.

On the Invertebrate Fauna of the Lower Oolites of Oxfordshire. By J. F. WHITEAVES, *F.G.S., Honorary Member of the Ashmolean Society, Oxford.*

Although the physical geology of the neighbourhood of Oxford is, with some exceptions, tolerably well understood, our knowledge of its palæontology, especially of the invertebrate division of the animal kingdom, is very meagre and unsatisfactory. The only exception I am aware of is a detailed list of the fossils of the Stonesfield Slate, in a paper contributed by Prof. Phillips to the volume of "Oxford Essays" for 1855, entitled "The Neighbourhood of Oxford and its Geology."

The following brief sketch of the Invertebrata obtained from the Great Oolite, Forest Marble, and Cornbrash during several years' collecting, must be considered as temporary only, nearly every day spent in practical investigation revealing fresh species, only a very small area having been carefully explored, and even that small area by no means so thoroughly as one could wish. Hence the few inductions that I have, as it seems to me, *legitimately* deduced from facts, must be considered as approximate results only in the present state of our knowledge. To Prof. Phillips's list of the fossils of the Stonesfield Slate, I am enabled to add twenty-eight species of Mollusca; these are,—

Ammonites Waterhousei, *Mor.* and *Lyc.*
Cerithium —— ?
Natica canaliculata ?, *Mor.* and *Lyc.*
Eulima communis, *Mor.* and *Lyc.* (casts only.
Nerita hemisphærica, *Roemer.*
—— minuta, *Sow.*
—— costulata, *Deshayes.*
—— rugosa, *Mor.* and *Lyc.*

Trochus spiratus, *D'Archiac.*
Pecten retiferus, *Mor.* and *Lyc.*
—— personatus, *Goldfuss.*
Hinnites abjectus, *Phil.*
Placunopsis radians ?, *Mor.* and *Lyc.*
—— socialis, *Mor.* and *Lyc.*
Pteroperna pygmæa, *Koch* and *Dunker.*
Gervillia aviculoides ?, *Sow.*
Modiola compressa, *Portlock.*
Cardium Stricklandi, *Mor.* and *Lyc.*
Opis lunulatus, *Sow.*
Astarte Wiltoni, *Mor.* and *Lyc.*
—— angulata, *Mor.* and *Lyc.*
—— squamula, *D'Arch.*
—— pumila, *Sow.*
Tancredia brevis, *Mor.* and *Lyc.*
—— curtansata, *Phillips.*
Quenstedtia oblita, *Mor.* and *Lyc.* (young.)
Corbula involuta, *Goldf.*
Pholas —— ?

We may add also, on the authority of Dr. Wright, two Echinoderms, viz. *Clypeus Plotii*, Klein, and *Pseudodiadema Parkinsoni*, Wright.

In deep cuttings on the Oxford, Worcester, and Wolverhampton Railway, between the Handborough and Charlbury stations (especially in two sections nearly opposite the village of Stonesfield), the lower zone of the Great Oolite is well exhibited. Near the Kirtlington station on the Great Western Railway several fine sections exposing the upper zone of the same formation may be studied with advantage: for detailed descriptions of these beds see Hull's Memoir on the Geology of the country round Woodstock. Up to the present date (June, 1860), the following is a list of the Invertebrata procured from these localities.

From the lower zone in the railway cuttings nearly opposite Stonesfield :—

Isastræa explanata, *M'Coy.*
—— Montlivaltia trochoides ?, *M.-Edw.*
Acrosalenia hemicidaroides, *Wr.*
Echinobrissus Woodwardi, *Wr.*
—— Griesbachii, *Wr.*
Clypeus Mülleri, *Wr.*
—— Rhynchonella concinna, *Sow.*
—— obsoleta, *Sow.*
Terebratula globata ?, *Sow.*
—— maxillata, *Sow.*
Ostrea Sowerbyi, *Mor.* and *Lyc.*
—— subrugulosa, *Mor.* and *Lyc.*
—— gregarea, *Sow.*
—— acuminata, *Sow.*
Placunopsis socialis, *Mor.* and *Lyc.*
Pecten lens, *Sow.*
—— vagans, *Sow.*
Gervillia acuta, *Sow.*
—— new sp.
Perna rugosa, *Mor.* and *Lyc.*
Lima cardiiformis, *Sow.*
—— duplicata, *Sow.*
Modiola imbricata, *Sow.*
Mytilus sublævis, *Sow.*
Arca æmula, *Phillips.*
Macrodon Hirsonensis, *D'Arch.*
Trigonia Moretoni, *Mor.* and *Lyc.*
Cardium Buckmani, *Mor.* and *Lyc.*
—— Stricklandi, *Mor.* and *Lyc.*
Cypricardia Bathonica, *D'Orb.*
—— nuculiformis, *Roemer.*
—— rostrata, *Sow.* (casts.)
Astarte angulata, *Mor.* and *Lyc.*
Cyprina Loweana, var., *Mor.* and *Lyc.*
Tancredia brevis, *Mor.* and *Lyc.*
—— new sp.
Neæra Ibbetsoni, *Morris.*
Myacites dilatus ?, *Phil.*
Pholadomya ovulum, *Mor.* and *Lyc.*
—— Heraulti, *Ag.*
Cylindrites angulatus ?, *Mor.* and *Lyc.*
Stomatia Buvignieri, *Mor.* and *Lyc.*
Monodonta Labadyei, *D'Archiac.*
Trochus Ibbetsoni, *Mor.* and *Lyc.*
Nerita rugosa, *Mor.* and *Lyc.*
—— costulata, *Desh.*
—— hemisphærica, *Roem.*
Natica Michelini, *D'Arch.*
Chemnitzia, new sp.
Nerinæa Eudesii, *Desl.*
—— Voltzii, *Desl.*

From the upper zone, at the Kirtlington railway station and at Enslow Bridge.—By far the larger portion of this assemblage was obtained from the beds marked G. in Professor Phillips's description of the section at the Kirtlington railway station. The species marked with an asterisk were procured from the Enslow Bridge quarries.

Anabacia orbulites, *Lamx.*

*Clypeus Plotii, *Klein.*
*—— Mülleri, *Wright.*
Acrosalenia hemicidaroides, *Wr.*

Diastopora diluviana, *M.-Edwards.*

Rhynchonella concinna, *Sow.*
Terebratula maxillata, *Sow.*
—— digona, *Sow.*
Placunopsis socialis, *Mor.* and *Lyc.*
*Pecten arcuatus, *Sow.*
—— annulatus, *Sow.*
Pteroperna costatula, *Desl.*
—— emarginata, *Mor.* and *Lyc.*
Gervillia acuta, *Sow.*
—— monotis, *Desl.*

Gervillia ovata, *Sow.*
—— crassicosta, *Mor.* and *Lyc.*
Lima cardiiformis, *Sow.*
Pinna cuneata, *Phillips.*
Modiola imbricata, *Sow.*
Arca Prattii, *Mor.* and *Lyc.*
—— æmula, *Phillips.*
Cucullæa ——?
Nucula Menkii, *Roemer.*
—— variabilis, *Sow.*
Limopsis ooliticus, *D'Archiac.*
Cardium subtrigonum, *Mor.* and *Lyc.*
—— Stricklandi, *Mor.* and *Lyc.*
—— incertum, *Phillips* (fide *Lycett*).
—— new sp.
Lucina striatula, *Buvign.*
—— cardioides, *D'Archiac.*
Sphæra Madridi, *Mor.* and *Lyc.*
Cypricardia rostrata, *Sow.*
Astarte squamula, *D'Archiac.*
—— Wiltoni, *Mor.* and *Lyc.*
*—— extensa, *Phillips.*
Cyprina Loweana, *Mor.* and *Lyc.*
—— depressiuscula, *Mor.* and *Lyc.*
Tancredia, new sp.
Corbula involuta, *Goldf.*
—— new sp.
Neæra Ibbetsoni, *Morris.*
*Myacites Scarburgensis, *Phillips.*
—— calceiformis, *Phillips.*
—— decurtatus, *Phillips.*

*Pholadomya Heraulti, *Agass.*
*—— solitaria, *Mor.* and *Lyc.*
Actæonina olivæformis, *Dunker.*
—— bulimoides, *Mor.* and *Lyc.*
—— parvula, *Roemer.*
*Cylindrites brevis, *Mor.* and *Lyc.*
—— new sp.
Bulla, new sp.
Patella cingulata, *Goldfuss.*
Phasianella elegans, *Mor.* and *Lyc.*
—— Leymeriei, *D'Archiac.*
Monodonta Labadyei, *D'Archiac.*
Trochus spiratus, var., *D'Archiac.*
—— Ibbetsoni?, *Mor.* and *Lyc.*
Nerita minuta, *Sow.*
Nerita hemisphærica, *Roemer.*
Rissoina acuta, *Sow.*
—— new sp.
Chemnitzia, new sp.
Eulima communis, *Mor.* and *Lyc.*
Natica intermedia, *Mor.* and *Lyc.*
—— ——?
Ceritella rissoides, *Buv.*
—— unilineata, *Sow.*
Nerinæa Eudesii, *Desl.*
—— Voltzii, *Desl.*
*—— funiculus?, *Desl.*
Cerithium, new sp.
Alaria trifida, *Phillips.*
—— lævigata, *Mor.* and *Lyc.*
*Ammonites subcontractus, *Mor.* and *Lyc.*

Until the publication of the Monograph on the Mollusca of the Great Oolite (by Messrs. Morris and Lycett), but little was known respecting the fossils of this formation. This monograph, too, was not so much an account of English Great Oolite fossils in general, as of a particular assemblage, restricted for the most part to a limited area around Minchinhampton. The above lists of species appear to me chiefly interesting as tending to remove the apparent isolation of the Minchinhampton fauna. As in Gloucestershire, so in Oxfordshire, the Cephalopoda seem to be but sparingly distributed in the Great Oolite; and but few species of carnivorous Gasteropods have yet been detected in the same formation near Oxford.

As compared with the same zone of life at Minchinhampton, the upper beds of the Oxfordshire Great Oolite would seem apparently to have been deposited in seas of greater depth and of more tranquillity. Bivalves are commonly found with the valves united and the ligament preserved, and large reef-like masses of coral are not unfrequent. In Oxfordshire a large proportion of the Great Oolite fossils range upwards into the Forest Marble and Cornbrash, and no inconsiderable series occur even as high as the Coralline Oolite. Five species have not previously been detected in this formation, and eleven shells are quite new to science. From the Forest Marble at Islip and Kidlington I have collected the following species:—

Anabacia orbulites, *Lamx.*

Cricopora straminea, *Phillips.*

Rhynchonella concinna, *Sow.*
Terebratula cardium, *Lam.*
—— var. bifurcata.
Ostrea Sowerbyi, *Mor.* and *Lyc.*
—— acuminata, *Sow.*
Pecten rigidus, *Sow.*
—— annulatus, *Sow.*
—— lens, *Sow.*
—— arcuatus, *Sow.*
—— personatus, *Goldf.*

Placunopsis socialis, *Mor.* and *Lyc.*
Gervillia acuta, *Sow.*
Pteroperna costatula, *Desl.*
Lima cardiiformis, *Sow.*
—— duplicata, *Sow.*
Arca minuta, *Sow.*
Nucula variabilis, *Sow.*
Leda lacryma, *Sow.*
Limopsis ooliticus, *D'Arch.*
Trigonia Moretoni, *Mor.* and *Lyc.*
—— costata, *Sow.*
Cardium Stricklandi, *Mor.* and *Lyc.*
Cypricardia rostrata, *Sow.*
Astarte interlineata, *Lyc.*

Astarte minima, *Phil.*
—— new sp.
Cyprina Loweana, *Mor.* and *Lyc.*
Corbis, new sp.
Tancredia truncata, *Lyc.*
Corbula involuta, *Goldf.*
—— Macneilii, *Morris.*
—— new sp.
—— new sp.
Pholadomya acuticosta, *Sow.*
Cerithium quadricinctum, *Goldfuss.*
Ceritella acuta, *Mor.* and *Lyc.*
—— longiscata, *Buv.*
Eulima communis, *Mor.* and *Lyc.*
Rissoina duplicata, *Sow.*
—— lævis, *Sow.*
—— new sp.
Nerita minuta, *Sow.*
Trochus spiratus, *D'Arch.*
—— Ibbetsoni, *Mor.* and *Lyc.*
Crossostoma discoideum, *Mor.* and *Lyc.*
Pagodus nodosa, *Mor.* and *Lyc.*
Patella cingulata, *Goldf.*
Emarginula scalaris, *Sow.*
Cylindrites acutus, *Sow.*
Actæonina Luidii, *Mor.*

The similarity between the fossils of this group and those of the Great Oolite is very remarkable; many Minchinhampton fossils occur in it which, as yet, I have been unable to detect in the Great Oolite of this district. Teeth of fishes, which are so abundant in the Wiltshire Forest Marble, appear to be somewhat rare in the same beds in Oxfordshire. The Cornbrash at Islip and Kidlington has yielded the following assemblage.

Cidaris Bradfordiensis, *Wr.* (plates and spines).
Pedina Smithii, *Forbes.*
Acrosalenia hemicidaroides, *Wr.*
—— spinosa, *Agassiz.*
Stomechinus intermedius, *Agassiz* (with spines attached).
Holectypus depressus, *Leske.*
Echinobrissus clunicularis, *Llhwyd.*
Clypeus Plotii, *Klein.*
Pygurus Michelini, *Cotteau.*

Anabacia orbulites, *Lamx.*

Alecto dichotoma, *Lamx.*
Diastopora diluviana, *Milne-Edw.*
Cricopora straminea, *Phillips.*

Rhynchonella Morieri, *Dav.*
—— concinna, *Sow.*
Terebratella hemisphærica, *Sow.*
Terebratula cardium, *Lamarck.*
—— intermedia, *Sow.*
—— obovata, *Sow.*
Ostrea Sowerbyi, *Mor.* and *Lyc.*
—— acuminata, *Sow.*
—— costata, *Sow.*
Placunopsis socialis, *Mor.* and *Lyc.*
Pecten vagans, *Sow.*
—— hemicostatus, *Mor.* and *Lyc.*
—— arcuatus, *Sow.*
—— lens, *Sow.*
—— annulatus, *Sow.*
—— personatus, *Goldfuss.*
Gervillia acuta, *Sow.*
—— ovata, *Sow.*
—— new sp.
Lima duplicata, *Sow.*
—— gibbosa, *Sow.*
—— cardiiformis, *Sow.*
Lima impressa, *Mor.* and *Lyc.*
Mytilus sublævis, *Sow.*
Modiola Sowerbyana, *Bronn.*
—— compressa, *Portlock.*
—— bipartita ?, *Sow.*
—— aspera, *Sow.*
—— imbricata, *Sow.*
Lithodomus inclusus, *Phillips.*
Macrodon Hirsonensis, *D'Archiac.*
Arca æmula, *Phillips.*
Nucula Menkii, *Roemer.*
—— variabilis, *Sow.*
Leda mucronata, *Sow.*
—— lacryma, *Sow.*
Trigonia Moretoni, *Mor.* and *Lyc.*
—— costata, *Sow.*
—— Goldfussi, *Ag.*
Cardium Buckmani, *Mor.* and *Lyc.*
—— Stricklandi, *Mor.* and *Lyc.*
—— subtrigonum, *Mor.* and *Lyc.*
—— —— ?
Cypricardia rostrata, *Sow.* (casts).
—— Bathonica ?, *D'Orb.*
Cyprina Loweana, *Mor.* and *Lyc.*
Isocardia minima, *Sow.*
Corbula involuta, *Goldf.*
—— Macneilii, *Morris.*
—— new sp.
Ceromya —— ?
Pholadomya lyrata ?, *Sow.*
—— deltoidea, *Sow.*
Myacites gibbosus, *Sow.*
—— decurtatus, *Phillips.*
—— securiformis, *Phillips.*
Gresslya peregrina, *Phillips.*
Patella cingulata, *Goldfuss.*
Trochus —— ?
Monodonta, new sp.
Chemnitzia variabilis, *Mor.* and *Lyc.*
Actæonina Luidii, *Morris.*

A careful study of the fossils of the Oxfordshire Cornbrash appears to me by no means favourable to that theory of Professor Buckman, that the Cornbrash assemblage of fossils, on the whole, more strongly resembles the fauna of the Inferior than that of the Great Oolite.

Very few of the fossils common to both the Cornbrash and Inferior Oolite are not found in the intermediate formation; and in the above list of Cornbrash fossils, a large per-centage are well-known Great Oolite species. The great comparative rarity of the Cephalopoda is also noticeable, both in the Cornbrash and Forest Marble; one solitary, mutilated fragment of an ammonite in the Islip Cornbrash is the only example of this class I have seen from these two formations during several years active collecting.

On the Intermittent Springs of the Chalk and Oolite of the Neighbourhood of Scarborough. By Captain Woodall, *M.A., F.G.S.*

On the Avicula contorta *Beds and Lower Lias in the South of England. By* Thomas Wright, *M.D., F.R.S.E. and G.S.*

The black shales, with their interstratified sandstones and bone-beds which lie at the base of the Lias, have by one class of observers been grouped with the Lias, by others with the Trias; the author had made a series of observations on these beds, where they are exposed at Westbury, Wainlode, and Aust, on the banks of the Severn; and at Penarth and Watchet, on the shores of the Bristol Channel: in all these sections he had found several species of Conchifera, which are special to the beds, as *Avicula contorta*, Portl., *Pecten Valoniensis*, Defr., *Mytilus minutus*, Goldf., *Cardium Rhæticum*, Mer., *Lima præcursor*, Quenst., *Neoschizodus posterus*, Quenst., *Cardium*, sp., *Cypricardia*, sp., *Anomya*, sp., with several other small bivalve shells which he was unable to determine. He found the same beds at the base of the Lias in Warwickshire and Worcestershire; and they have recently been found in Staffordshire by Mr. Howell, and several years ago were discovered by General Portlock in Ireland. In Germany Quenstedt calls these beds Vorläufer des Lias; they are the true representatives of the Upper St. Cassian beds of German geologists, and the Kössenerschichten of the Tyrolese. Since they were first described by Von Buch thirty years ago, they have formed the subject of many interesting observations by continental geologists, although up to this time it has not been settled whether they belong to the Trias or to the Lias. The Conchifera found in these beds in England are special to them, and none of the species pass into the true Lias; whereas it has been asserted by Sir Philip Egerton and Professor Agassiz that the species of fishes found in the Bone-beds of England and Ireland are Triassic forms. Should this statement hold good, the evidence for the triassic character of the *Avicula contorta* series will greatly preponderate over their liassic affinities. M. Jules Martin, in an able memoir, 'Paléontologie Stratigraphique de l'Infra-Lias du Département de la Côte-d'Or,' has examined these beds in the departments of Côte d'Or, Rhone, Ardeche and Isère, and has placed them all as Infra-lias. The absence of the Bone-bed from the French deposits, although found in Luxembourg, is remarkable; and therefore the evidence afforded by the fossil fishes is excluded from M. Martin's estimate of the Palæontological affinities of these Infra-Liassic deposits.

Dr. Wright divides the Lower Lias into six zones of life, each characterized by certain species of mollusca which are special to it; these are—1st, the zone of *Ammonites planorbis*; 2nd, the zone of *Ammonites Bucklandi*; 3rd, the zone of *Ammonites Turneri*; 4th, the zone of *Ammonites obtusus*; 5th, the zone of *Ammonites oxynotus*; and 6th, the zone of *Ammonites raricostaius*. Each of these zones was separately described, its fauna enumerated, and the localities where it was developed pointed out. The Lower Lias in the South of England was compared with the Lower Lias of Wurtemberg, and the correlations of that formation in both countries pointed out.

BOTANY AND ZOOLOGY, INCLUDING PHYSIOLOGY.

GENERAL.

On the Progress of Natural Science in the United States and Canada.

By PHILIP P. CARPENTER, *B.A., Ph.D.*

THE principal part of this communication was devoted to an explanation of the principles and working of the Smithsonian Institution at Washington, D.C. It was founded "for the increase and diffusion of knowledge among men," and was not restricted either by nation or "red tape." It gives aid to students in prosecuting any branch of research; carries on an extensive series of meteorological observations over the North American Continent; directs the Natural History observations of the various governmental Exploring Expeditions of the U.S. Government; superintends an intricate system of exchanges of books and specimens between individuals or Societies in Europe or America, in conjunction with the Royal Society, and with special exemption from customs; and gives to the world a large amount of original matter through the press. The entire Museum department of the United States Government, till lately deposited at the Patent Office, is now the property of the Smithsonian Institution, with authority to exchange duplicates. The publications consist of three classes—(1) the "Smithsonian Contributions to Knowledge," expensive works sold at cost price; (2) the "Miscellaneous Collections" of pamphlets, which are freely distributed; and (3) an annual volume of Reports, &c. published at Government expense. In regulating exchanges, whether of books or specimens, the directors do not require a *quid pro quo*, but simply a friendly reciprocity; their first desire being to make their materials *useful to science*, wherever that can best be done*.

The Federal Government, as well as most of the Sovereign States, have published Reports on Geology and other branches of science, many of which are of the highest value. The ten quarto volumes on the 'Pacific Railroad,' abounding in plates, contain a complete *résumé* of the Natural History of the great western deserts and the Rocky Mountains, and may be purchased in Washington for about £5. The State of Massachusetts is giving liberal aid to Professor Agassiz in forming a magnificent museum at Cambridge University, which will be arranged geographically. There is already a vast amount of material accessible to students, and of duplicates for exchanges. The State Museum at Albany is under the direction of the Regents of the University of New York. They have a large number of duplicate palæozoic fossils, available for exchange. The Academy of Natural Science of Philadelphia, the Lyceum of New York, and the Natural History Society of Boston, are well known by their publications. The Colleges of Yale, Amherst, and Charleston, S.C., have also done good service to science. In Canada, the Geological Survey under Sir W. Logan is not surpassed by any for admirable arrangement. The Natural History Societies both of Montreal and of Toronto publish periodicals. In M'Gill College, Montreal, under Professor Dawson, and in the University of Toronto, under Professor Hincks, the study of natural science is steadily increasing. The importance of the magnetic observations at Toronto is well known; and a system of recording meteorological information, at the public grammar schools of Canada West, is now being organized in connexion with the Smithsonian Institution.

Remarks on the Final Causes of the Sexuality of Plants, with particular reference to Mr. Darwin's *Work 'On the Origin of Species by Natural Selection.' By* C. J. B. DAUBENY, *M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford.*

Dr. Daubeny began by pointing out the identity between the two modes by which the multiplication of plants is brought about, the very same properties being imparted to the bud or to the graft, as to the seed produced by the ordinary process of fecundation; and a new individual being in either instance equally produced.

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* All communications to the Smithsonian Institution should be addressed to "Professor Henry, Secretary of the Smithsonian Institution, Washington, D.C., U.S.A."

We are therefore led to speculate as to the final cause of the existence of sexual organs, in plants, as well as in those lower animals which can be propagated by cuttings.

One use, no doubt, may be the dissemination of the species; for many plants, if propagated by buds alone, would be in a manner confined to a single spot. Another secondary use is the production of fruits which afford nourishment to animals. A third may be to minister to the gratification of the senses of man by the beauty of their forms and colours.

But as these ends are only answered in a small proportion of cases, we must seek further for the uses of the organs in question; and hence the author suggested, that they might have been provided, in order to prevent that uniformity in the aspect of Nature which would have prevailed if plants had been multiplied exclusively by buds.

It is well known that a bud is a mere counterpart of the stock from whence it springs, so that we are always sure of obtaining the very same description of fruit by merely grafting the bud or cutting of a pear or apple tree upon another plant of the same species.

On the other hand, the seed never produces an individual exactly like the plant from which it sprung, and hence by the union of the sexes in plants some variation from the primitive type is sure to result.

Dr. Daubeny remarked, that if we adopt in any degree the views of Mr. Darwin with respect to the origin of species by natural selection, the creation of sexual organs in plants might be regarded as intended to promote this specific object. Whilst, however, he gave his assent to the Darwinian hypothesis, as likely to aid us in reducing the number of existing species, he wished not to be considered as advocating it to the extent to which the author seems disposed to carry it. He rather desired to recommend to Naturalists the necessity of further inquiries, in order to fix the limits within which the doctrine proposed by Darwin may assist us in distinguishing varieties from species.

BOTANY.

Dr. DAUBENY invited the Members to visit an experimental garden under his superintendence in the neighbourhood of Oxford, in which he had been carrying on some investigations connected with Agricultural Chemistry, the nature of which he proposed to explain on the spot.

On a Plant Poisoning a Plant. By R. DOWDEN.

On Abnormal Forms of Passiflora cærulea. *By* Dr. C. DRESSER.

On the Morpholcgical Laws in Plants. By Dr. C. DRESSER.

On the supposed Germination of Mummy Wheat.
By the Rev. Professor HENSLOW, *M.A., F.L.S.*

The author introduced his observations by reading a letter from Professor Wartmann, of Geneva, who had recently found that seeds might be exposed to a temperature of 198° below zero of Fahrenheit's scale, without losing the power of germination. Professor Henslow had himself exposed seeds to the temperature of boiling water, and they germinated. The question of how long seeds would retain their vitality was one of great interest; and a Committee of this Association had reported on the subject, but they had not succeeded in making seeds grow which had been kept more than two centuries. He then showed that experiments recorded on the growth of mummy wheat were not trustworthy; and especially noticed the case which had been relied on so much, of the growth of mummy wheat by Mr. Tupper from seeds supplied him by Sir Gardner Wilkinson. He alluded to a sample of mummy wheat which he had carefully inspected grain by grain, and found among it two grains of a different variety from the rest; these were perfectly fresh, whereas the others were dark-coloured, with decided indications of decomposition and partial charring. Upon inquiry he was able to ascertain that this sample was a portion of a large stock, which had been taken from a catacomb some years previously, and had been exposed for sale in the jars of a corn merchant at Cairo. There could be no doubt an accidental admixture of a few recent grains left in the jars had taken place. In samples supplied by Sir G. Wilkinson to the late Robert Brown for the purpose of experiment, the latter had found in it a few grains of Indian corn! He thought it not at all improbable that the samples he had examined, and those furnished by Sir G. Wilkinson, might have formed portions of the same stock.

*On the Distinctions of a Plant and an Animal, and on a Fourth Kingdom of Nature**. *By* JOHN HOGG, *M.A., F.R.S., F.L.S., &c.*

The author stated the great difficulty he had long experienced when examining some of the simpler living beings, in defining the characters of those primary forms of life, whether they belong to the vegetable or animal kingdom; and he considered that there may strictly be *no* distinction in nature between those kingdoms; and that *life* in the lowest animal, as well as in the simplest plant, may be the *same*; still that it is necessary to draw a line of demarcation between them, for the purpose of classifying the numerous creatures or organisms existing in the world. Mr. J. Hogg then showed that he had, more than twenty years ago, demonstrated that locomotion, although apparently spontaneous, was no distinction of animality. Neither could the presence of iodine nor of starch be accounted a satisfactory test of vegetability. So the four chemical elements, hydrogen, carbon, nitrogen, and oxygen, have been regarded for the same objects, though without positive success; and even the green colouring matter, called "chromule," or "chlorophyll" (once supposed to belong exclusively to vegetables), has been shown to be likewise present in certain of the lower animals. But the author observed that the "two principal characteristics of an animal are undoubtedly the muscular and nervous systems, which do not exist in a plant, and which Prof. Owen has not included in his definitions of a plant and an animal given in his new work on 'Palæontology.'" Mr. J. Hogg then referred to Linnæus's arrangement of all natural bodies into *three* kingdoms, and, after quoting his definitions of Lapides, Vegetabilia, and Animalia, said that they must at this day be accounted as insufficient and too concise; and, considering the great extension of science, both in Zoology and Botany, which had taken place since the time of Linnæus, he attempted to enlarge the definitions of those three divisions of natural bodies thus:—*Minerals* are bodies, hard, aggregative, simple, or component, having bulk, weight, and often regular form; but inorganic, inanimate, indestructible by death, insentient, and illocomotive. *Vegetables* are beings, organic, living, nourishable, stomachless, generative, destructible by death, possessing some sensibility, sometimes motive, and sometimes locomotive in their young or seed state; but inanimate, insentient, immuscular, nerveless, and mostly fixed by their roots. *Animals* are beings, organic, living, nourishable, having a stomach, generative, destructible by death, motive, animate, sentient, muscular, nervous, and mostly spontaneously locomotive, but sometimes fixed by their bases.

Further, as regards a *fourth* kingdom of Nature, the author having perused Prof. Owen's 'Palæontology,' published this year, found that he had introduced the "Kingdom Protozoa," and placed it before the "Kingdom Animalia." He proved that there were objections to the term "Protozoa," which was formed by a foreign naturalist, and that it could not include those lower organisms, whose nature partook more of *plants* (Phyta) than of *animals* (Zoa) without creating errors; and since it appears to many desirable to place those organic beings which are of a doubtful nature in a fourth or an additional kingdom, he suggested one under the title of the Primigenal Kingdom,—Regnum Primigenum continens Protoctista, *i. e.* Protophyta et Protozoa. This would comprise all the lower creatures, or the *primary organic beings*—"Protoctista," from πρῶτος, *first*, and κτιστὰ, *created beings*—both Protophyta and Protozoa; and would also include the Sponges or Amorphozoa of M. de Blainville, although Mr. J. Hogg thought it better to substitute for the latter the name of Amorphoctista, derived from ἄμορφος, *formless*, and κτιστὰ, *creatures* or *organisms*.

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* This entire paper, with the coloured Diagram, is published in the 'Edinburgh New Philosophical Journal,' vol. xii. (new series) for October 1860, pp. 216–225.

Some having compared the Vegetable and Animal Kingdoms to *two* pyramids, which diverge from each other as they ascend, but are placed on a common base, the author conceived that that *base* might fairly represent the Primigenal Kingdom, which embraces the lower or primary organisms of both the former, but which are of a doubtful nature, and can, in some instances, only be considered as having become blended or mingled together.

An accompanying diagram was exhibited, which represented the two pyramids springing from the same base: one, coloured yellow, denoted the Vegetable Kingdom; the other was tinged blue, and signified the Animal Kingdom; whilst the base, common to both, was coloured green, which was intended to show by the *union* of the two former colours the blending of the two natures of the lower created beings comprised in the *fourth*, or Primigenal Kingdom. These pyramids, with their base, stood on a foundation tinged brown, thereby signifying the earth and the Mineral Kingdom.

On the Normal and Abnormal Variations from an assumed Type in Plants.

By M. T. MASTERS.

The paper was illustrated by a large number of recent and dried forms of monstrous plants and parts of plants.

In this paper there was an attempt to show that no definite limits could be drawn between what are termed Variations and Monstrosities. Numerous instances of extreme degrees of variation and of polymorphism in plants, apparently dependent on external circumstances, were exhibited; among them two specimens of *Ficus stipularis*, the one taken from a plant grown against a wall, the other from a plant of the same species, and derived from the same original stock, but which had been treated as a standard. The differences in habit, size, form and texture of the leaves and other parts were such, that had the two specimens not been taken from the same plant, it would have been difficult to believe that they could have belonged to the same species. Allusion was made to the changes that naturally take place during the growth of some plants, and to the fact that a condition which is unnatural in one plant is the common condition in another. So also irregularity of growth, as it is the constant condition in some plants, and for many other reasons, cannot be considered an abnormal variation. On the other hand, Peloria, or a return to typical regularity, can hardly be considered abnormal. Again, certain changes which are physiologically abnormal are not so morphologically. The paper concluded with a review of the principal points of distinction between variations and malformations, a review which showed that no arbitrary line could be drawn between them.

On the Structure of Fern Stems. By G. OGILVIE, *M.D.*

The object of this communication was to determine the arrangement and relations of those tissues in Ferns commonly regarded as analogous to the vascular and woody elements of the stems of the higher plants.

In the case of the former the correspondence may be admitted without much hesitation, from the close resemblance of the vascular bundles of ferns to those of endogenous stems; the fasciculi in both being imbedded separately in the general parenchyma, and each surrounded by a layer of soft cambium tissue. The peculiarities of the Fern consist in the polygonal form and ladder-like or scalariform markings of its elongated cells or vessels, and in the disposition of the fasciculi, so as to form, by their anastomosis, the reticulated wall of a hollow cylinder, imbedded in the general parenchyma of the stem—an arrangement which is rarely departed from in our British ferns, though in *Pteris aquilina* we find in addition two broad vascular bands in the central part of the stem, and in *Osmunda* and *Hymenophyllum* we have the netted cylinder replaced by a central vascular cord, as in the Lycopodiaceæ. The correspondence of the hard tissues to the true stem-wood of the higher plants is more open to objection, notwithstanding the occasional resemblance in their minute structure. The so-called woody fibres of ferns are never, like those of the Phanerogamia, associated with the vessels in the same fasciculus or layer; nor are they ever surrounded by a stratum of cambium tissue; but they are merely indurated and transformed portions of the general parenchyma, and this even when, as in some species, they form a sort of outer sheath to the fasciculi. Its great variability is another point which assimilates this element rather to such sclerogenous formations of the higher plants as nut-shells and other husky tissues, than to the proper wood of their stems. In some it occurs only as a thin cortical coating (*Polypodium, Lastrea Filix-Mas, Asplenium Filix-Fœmina*); in others it constitutes the entire mass of the rhizome, except a thin sheath of soft tissue surrounding the vascular bundles (*Blechnum, Osmunda, Hymenophyllum*); while there are various intermediate forms in which it occurs in the guise of isolated nodules or filaments (*Lastrea dilatata, L. oreopteris*) of sheaths to the vascular bundles (*Asplenium*), or of one or more longitudinal tracts (*Allosorus, Pteris*). [These variations were illustrated by magnified sectional views of thirteen species, mostly British.]

The true homologue of the stem-wood of the Phanerogamia is to be sought, it has been suggested, in a fibrous stratum which occurs in the fasciculi of some tree ferns, immediately within the cambium layer; for though these fibres have nothing of a woody character, and are mostly represented in our indigenous species only by an outer series of small and imperfectly developed scalariform vessels, it is the outer layer corresponding to them which is woody in the fasciculi of the endogenous stem, and in all the cases its development seems to show that it arises from a peculiar transformation of the cells of the cambium tissue.

ZOOLOGY.

On the Acclimatization of Animals, Birds, &c., in the United Kingdom. *By* FRANK T. BUCKLAND.

Remarks on the Respiration of the Nudibranchiate Mollusca. By CUTHBERT COLLINGWOOD, *M.B., F.L.S., &c., Professor of Animal Physiology in Queen's College, Liverpool.*

The author described and exhibited drawings of a remarkable immature form of *Triopa claviger*, which had led to the observations he was about to make, more especially on account of the entire absence of the branchial plumes. He canvassed the various definitions given by authors of the term Nudibranchiata, and showed that, although it might with accuracy be applied to the family Dorididæ, the Æolididæ could not with propriety be called Nudibranchs, inasmuch as their papillæ were neither anatomically nor morphologically to be regarded as gills. These mollusks all respired by the whole surface of the body, more or less; and the author suggested that in the Doridinæ the appendages to the body were supplementary to the branchial plumes; which, as a rule, were less developed in them than in the true Dorids, which were without such appendages. The fact, however, that there was no specialized apparatus for respiration in the Æolididæ, coupled with many analogies which that family bore to animals much lower in the scale of organization, seemed to separate them much more widely from the Nudibranchiata proper than was generally allowed.

On the Nudibranchiate Mollusca of the Mersey and Dee. By CUTHBERT COLLINGWOOD, *M.B., F.L.S., &c., Professor of Animal Physiology in Queen's College, Liverpool.*

The author dwelt particularly upon the richness of the estuaries of these rivers in this beautiful group, and especially referred to some very interesting forms, such as *Doris depressa, D. subquadrata, D. proxima*, and *Eolis Landsburgii, E. concinna*, &c., which were found in them. The most interesting of all, however, was *Antiopa hyalina*, a very local species, only found at Hilbre Island, in the Dee, where it was discovered by Mr. Byerley, and where the present writer had found it in the same rock-pool, with its congener *A. cristata*. He submitted the following

Catalogue of the Nudibranchiata of the Mersey and Dee.

1. Doris tuberculata. Mersey and Dee; common.
2. —— Johnstoni. Mersey and Dee; once or twice.
3. —— proxima. Mersey and Dee; common (nowhere else).
4. —— bilamellata. Mersey and Dee; abundant.
5. —— pilosa. Mersey and Dee; not uncommon.
6. —— subquadrata. Dee; once (the second known specimen).
7. —— depressa. Dee; once.
8. Polycera Lessonii. Mersey; occasional.
9. —— ocellata. Mersey and Dee; occasional.
10. Ancula cristata. Mersey and Dee; common.
11. Tritonia Hombergii. Mersey and Dee; occasional.
12. —— plebeia. Mersey and Dee; occasional.
13. Dendronotus arborescens. Mersey and Dee; common.
14. Doto coronata. Mersey and Dee; very common.
15. Eolis papillosa. Mersey and Dee; common.
16. —— coronata. Mersey and Dee; common.
17. —— Drummondi. Mersey and Dee; very common.
18. —— rufibranchialis. Mersey and Dee; not uncommon.
19. —— Landsburgii. Mersey and Dee; rare.
20. —— concinna. Mersey; common (the second known locality).
21. —— olivacea. Dee (once taken).
22. —— aurantiaca. Mersey and Dee; common.
23. —— picta. Mersey and Dee; not uncommon.
24. —— exigua. Mersey; apparently rare.
25. —— despecta. Mersey; common.
26. Embletonia pallida. Mersey (the only known locality); very rare.
27. Antiopa cristata. Dee; occasional.
28. —— hyalina. Dee (the only known locality); very rare.

On Recurrent Animal Form, and its Significance in Systematic Zoology. By Cuthbert Collingwood, *M.B., F.L.S., &c., Professor of Animal Physiology in Queen's College, Liverpool.*

The object of this paper was to call attention to the frequent recurrence of similar forms in widely-separated groups of the animal kingdom; similarities, therefore, which were unaccompanied by homologies of internal structure. These analogies of form had greatly influenced the progress of classification, by attracting the attention of systematizers, while as yet structural homologies were imperfectly understood; and, as a consequence, many groups of animals had been temporarily located in a false position, such as bats and whales by the ancients, and the Polyzoa and Foraminifera in more modern times. These resemblances in form were illustrated generally by the classes of Vertebrata, and more especially by the various orders of Mammalia,—the Invertebrata affording, however, many remarkable examples. Since no principle of gradation of form would sufficiently account for these analogies, the author had endeavoured to discover some other explanation, and had come to the conclusion, that the fact of deviations from typical *form* being accompanied by modifications of typical *habits*, afforded the desired clue. Examples of this were given, and the principle educed, that *agreement of habit and economy in widely separated groups is accompanied by similarity of form*. This position was argued through simple cases to the more complex, and the conclusion arrived at that, where habits were *known*, the explanation sufficed; and it was only in the case of animals of low organization and obscure or unknown habits, that any serious difficulty arose in its application; so that our appreciation of the *rationale* of their similarity of form was in direct ratio to our knowledge of their habits and modes of life. In conclusion, by a comparison of the Polyzoa with the Polyps, it was shown that the economy of both was nearly identical, although they possessed scarcely anything in common except superficial characters; and this identity of habit was regarded as the explanation of their remarkable similarity of form.

This paper is published (as read before the Section) in the 'Annals of Natural History,' for August 1860; and still more at length in the volume of 'Proceedings of the Liverpool Literary and Philosophical Society' for the past Session.

Dr. **Daubeny** gave an account of some experiments he had performed on the subject of Equivocal Generation. He described the apparatus he had employed, and stated that, even after vegetable matter had been exposed to a temperature exceeding 300° of Fahr., and had been subsequently brought into contact with nothing but water carefully distilled, and with air that had been passed through sulphuric acid, indications of organic life were discoverable in it.

Dr. Daubeny stated that Dr. Bowerbank and other gentlemen had examined the flasks in which he had performed his experiments on Equivocal Generation. No animal life was to be found, but a few filaments of fungi were visible. As the latter might possibly have been derived from the cork and linseed-meal, as was suggested by Dr. Bowerbank, he proposed to repeat the experiment under circumstances which would eliminate these sources of error.

On the Intellectual Development of Europe, considered with reference to the views of Mr. Darwin *and others, that the Progression of Organisms is determined by Law. By* Professor Draper, *M.D., New York.*

The object of this paper was to show that the advancement of Man in civilization does not occur accidentally or in a fortuitous manner, but is determined by immutable law.

The author introduced his subject by recalling proofs of the dominion of law in the three great lines of the manifestation of life:—first, in the successive stages of development of every individual from the earliest rudiment to maturity; second, in the numberless organic forms now living contemporaneously with us, and constituting the animal series; third, in the orderly appearance of that grand succession, which in the slow lapse of geological time has emerged, constituting the life of the earth, showing therefore not only the evidences, but also proofs of the dominion of law over the world of life.

In these three lines of life he maintained that the general principle is to differentiate instinct from automatism, and then to differentiate intelligence from instinct. In man himself three distinct instrumental nervous mechanisms exist, and three distinct modes of life are perceptible, the automatic, the instinctive, the intelligent. They occur in an epochal order, from infancy through childhood to the more perfect state.

Such holding good for the individual, it was then affirmed that it is physiologically impossible to separate the individual from the race, and that what holds good for the one holds good for the other too, and hence that man is the Archetype of Society, and individual development the model of social progress, and that both are under the control of immutable law; that a parallel exists between individual and natural life in this, that the production, life, and death of an organic particle in the person, answers to the production, life, and death of a person in the nation.

Turning from these purely physiological considerations to historical proof, and selecting the only European nation which thus far has offered a complete and completed intellectual life, Professor Draper showed that the characteristics of Greek mental development answer perfectly to those of individual life, presenting philosophically five well-marked ages or periods, the first being closed by the opening of Egypt to the Ionians; the second, including the Ionian, Pythagorean, and Eleatic philosophers, was ended by the criticisms of the Sophists; the third, embracing the Socratic and Platonic, by the doubts of the Sceptics; the fourth, ushered in by the Macedonian expedition and adorned by the splendid achievements of the Alexandrian School, degenerated into Neoplatonism; and imbecility in the fifth, to which the hand of Rome put an end. From the solutions of the four great problems of Greek philosophy, given in each of these five stages of its life, he showed that it is possible to determine the law of the variation of Greek opinion, and to establish its analogy with that of the variations of opinion in individual life.

Next, passing to the consideration of Europe in the aggregate, Professor Draper showed that it has already in part repeated these phases in its intellectual life. Its first period closes with the spread of the power of Republican Rome, the second with the foundation of Constantinople, the third with the Turkish invasion of Europe; we are living in the fourth. Detailed proofs of the correspondence of these periods to those of Greek life, and through them to those of individual life, are given in a work now printing on this subject by the author in America.

Having established this conclusion, Professor Draper next briefly alluded to many collateral problems or inquiries. He showed that the advances of men are due to external and not to interior influences, and that in this respect a nation is like a seed, which can only develope when the conditions are favourable, and then only in a definite way; that the time for psychical change corresponds with that for physical, and that a nation cannot advance except its material condition be touched, this having been the case throughout all Europe, as is manifested by the diminution of the blue-eyed races thereof; that all organisms, and even man, are dependent for their characteristics, continuance, and life, on the physical conditions under which they live; that the existing apparent invariability presented by the world of organization is the direct consequence of the physical equilibrium; but that, if that should suffer modification, in an instant the fanciful doctrine of the immutability of species would be brought to its proper value. The organic world appears to be in repose because natural influences have reached an equilibrium. A marble may remain motionless for ever on a level table, but let the table be a little inclined, and the marble will quickly run off, and so it is with organisms in the world. From his work on Physiology, published in 1856, he gave his views in support of the doctrine of the transmutation of species, the transitional forms of the animal and also the human type, the production of new ethnical elements or nations, and the laws of their origin, duration and death.

On some Specimens of Shells from the Liverpool Museum, originally from the Pathological Collection formed by the late Mr. Gaskoin. *By the* Rev. H. H. Higgins, *M.A., Rainhill, Liverpool.*

The late Mr. Gaskoin had in his museum a series of specimens, collected for the purpose of illustrating the pathology of the Mollusca. This series was in course of formation in the year 1835, from which period, to the time of his decease, Mr. Gaskoin devoted considerable attention to the selection, from various sources, of specimens of shells in any wise remarkable for distorted growth, or for the repair of injuries received during the life of the animal. I am not aware that Mr. Gaskoin published or left in manuscript any account of the result of his observations in this department of Natural History. It is evident that in any case of abnormal growth a second, and still more a third or a fourth, instance of the same kind may afford a fair ground for a conclusion, which, if based upon a single instance only, would be of little or no value. The extensive character of the series was in this respect very valuable. In the course of more than twenty years' collecting, Mr. Gaskoin had enriched his pathological cabinet, not only with a great variety of mended fractures and distorted growths, but with many duplicates, sometimes of cases apparently altogether exceptional, and likely to be unique. A select series of specimens was then exhibited to the Section, and remarks were made upon them, which can scarcely be presented intelligibly apart from the specimens themselves.

Notice of British Well Shrimps. By the Rev. A. R. Hogan, *M.A.*

The author exhibited specimens of some remarkable additions not long since made to our British Crustacea. They consisted of two species of *Niphargus* (*Fontanus* and *Kochianus*), and the new genus *Crangonyx*, with its single species *subterraneus* of Spence Bate. These species have been described and figured in the volume of the 'Natural History Review and Quarterly Journal of Science' for last year (1859). They are of great interest, as examples of a subterranean Fauna in England, analogous to that long known on the Continent and in America. The first established instance of the occurrence of Niphargi in England, was Mr. Westwood's discovery at Maidenhead, Berkshire, of a well containing numbers of *N. aquilex*. They have more recently been obtained from Corsham and Warminster, Wiltshire, and also from Ringwood, on the borders of the New Forest, Hampshire. *Crangonyx subterraneus* has occurred at the two latter places, but not at the first named. *Niphargus fontanus* is found at both Corsham and Ringwood, but with a difference in the shape of the gnathopoda and posterior pleopoda, amounting to a probably distinct variety, if not species. The form of the gnathopoda, or hands, is worthy of attention, being each armed with a moveable claw of large size, forming a prehensile organ of great power. *N. fontanus* is also possessed of small, yellow eyes, which distinguish it in a very marked way from the allied species (of the genus *Gammarus*) found on the Continent. Every member of the subterranean Fauna hitherto found has been destitute of eyesight. The movements of Niphargi, when kept in captivity, are interesting to observe; but Mr. Hogan states that he has found great difficulty in preserving them alive. The longest period during which even the strongest specimens survived its capture was three weeks. The average temperature of the water in which *Niphargus* and *Crangonyx* are found is about 50° Fahr., and they seem to propagate in recently-formed wells as freely as in old ones. In no case have any species of this family been found, either in this country or abroad, in open wells or other than artificial ones,—pumps, in fact. They are found at all seasons of the year, but most abundantly towards the end of the autumn. The largest size known among the English species (that of *N. fontanus*) hardly exceeds half an inch. Mr. Hogan hoped that more extended observations would be made in Great Britain on this interesting family of Crustacea, as their economy and structure are as yet very imperfectly known, and an accurate examination would be sure to reward the investigator with results at least as interesting as those already obtained regarding their allies by Continental naturalists.

Mr. J. G. JEFFREYS exhibited several specimens of the common whelk (*Buccinum undatum*) having double opercula; in one instance, a second or supplementary operculum being piled on the usual one; and in the others, there being two separate opercula, instead of one, in each whelk. He adverted briefly to the different kinds of monstrosity which occur in animals and plants, and said he believed this to be the first case of a similar monstrosity in the Mollusca. He observed that the monstrosity under consideration appeared to be congenital, and not to have arisen from an accidental loss of the original organ, because in some of the specimens both opercula were cases of hypertrophy, and in the others of atrophy; and he mentioned that all the specimens came from the same place (Sandgate in Kent), showing a repetition, and perhaps an hereditary transmission, of the same abnormal phenomenon; and he suggested that thus permanent varieties might in course of time be formed, and constitute what some naturalists would call "distinct species." He adduced in support of this view, the case of a reversed monstrosity of the common garden snail (*Helix aspersa*), having been bred for many years in succession by the late M. d'Orbigny in his garden at Rochelle, as well as many instances of a reversed form of almond whelk (*Fusus antiquus*) having occurred in the same localities on the coasts of England and Portugal, such being the normal form in the crag.

On the British Teredines, or Ship-Worms.

By J. G. JEFFREYS, *F.R.S.*

After observing that his researches had not been confined to the British Teredines, but that he had recently had an opportunity of meeting all the French naturalists who had published on the subject, as well as of studying all the accessible collections and books, he treated the matter first in a zoological point of view, and gave a short history of the genus *Teredo*, from the time of Aristotle and his pupil Theophrastus to the present time; especially noticing the elaborate monograph of Sellius, in 1733, on the Dutch ship-worm; the valuable paper of Sir Everard Home and his pupil Sir Benjamin Brodie, in 1806; and the physiological essays of Quatrefages, in 1849.

He showed that the *Teredo* undergoes a series of metamorphoses; the eggs being developed into a sub-larval form after their exclusion from the ovary, and remaining in the mantle of the parent for some time. In its second phase (or that of proper larvæ) the fry are furnished with a pair of close-fitting oval valves, resembling those of a *Cythere*, as well as with cilia, a large foot, and distinct eyes, by means of which it swims freely and with great rapidity, or creeps, and afterwards selects its fixed habitation. The larval state continues for upwards of 100 hours, and during that period the fry are capable of traversing long distances, and thus becoming spread over comparatively wide areas. The metamorphosis is not, however (as Quatrefages asserts), complete; because the young shell, when fully developed, retains the larval valves. He then discussed the different theories, as to the method by which the *Teredo* perforates wood, giving a preference to that of Sellius and Quatrefages, which may be termed the theory of "suction," aided by a constant maceration of the wood by water, which is introduced into the tube by the siphons. This process, according to Quatrefages, is effected by an organ which he calls the "*capuchon céphalique*," and which is provided with two pairs of muscles of extraordinary strength. Mr. Jeffreys was of opinion that the foot of the *Teredo* was the sole instrument of perforation. He instanced, in illustration of this theory, the cases of the common limpet, as well as of many bivalve mollusks, *Echinus lividus*, and numerous annelids, which excavate rocks to a greater or less depth; and he cited the adage of "Gutta cavat lapidem non vi sed sæpe cadendo," in opposition to the mechanical theory. The *Teredo* bores either in the direction of the grain or across it, according to the kind of wood and the nature of the species; the *Teredo Norvegica* usually taking the former course: every kind of wood is indiscriminately attacked by it. The *Teredines* constitute a peaceful, though not a social community; and they have never been known to work into the tunnel of any neighbour. If they approach too near to each other, and cannot find space enough in any direction to continue their operations, they enclose the valves or anterior part of the body in a case, consisting of one or more hemispherical layers of shelly matter. Sellius supposed that the *Teredo* ate up the wood which it excavated, and had no other food; and, labouring under the idea that it could no longer subsist after being thus voluntarily shut up, he considered it to be the pink of chivalry and honour, in preferring to commit suicide rather than infringe on its neighbour. In this enclosed state the valves often become so much altered in form, as well as in the relative proportion of their different parts, as not to be easily recognizable as belonging to the same species; and one species (*T. divaricata*) was constituted from specimens of *T. Norvegica* which had been so deformed. The food of the *Teredo* consists of minute animalcula, which are brought within the vortex of the inhalant siphon, and drawn into the stomach. The wood which has been excavated also undergoes a kind of digestion during its passage outwards through the long intestine. The animal has been proved by Laurent and other observers to be capable of renewing its shelly tube, and of repairing it in any part. It is stated by Quatrefages (and apparently with truth) that the sexes are separate, impregnation being effected in a similar mode to that which takes place among palm-trees and other diœcious plants. There appear to be only five or six males in one hundred individuals. The *Teredo* perforates and inhabits sound wood only, but an allied genus (*Xylophaga*) has been recently found to attack the submarine telegraph cable between this country and Gibraltar at a depth of from sixty to seventy fathoms, and to have made its way through a thick wrapper of cordage into the gutta percha which covered the wire. The penetration was fortunately discovered in time, and was not deep enough to reach the wire. He gave several instances to show the rapidity of its perforating powers,—one of them having been supplied by Sir Leopold M'Clintock while he was serving with the author's brother in the North Pacific.

Mr. Jeffreys traced the geographical distribution of the *Teredines*, and showed that at least two species, which are now found living on our own shores, occurred in the post-pleistocene period; and he inferred from the circumstance of one of these species having been found in fossil *drift* wood, that conditions similar to the present existed during that epoch. Some species inhabit fixed wood, and may be termed ittoral," while others are only found in floating wood, and appear to be "pelagic." Each geographical district has its own "littoral" species, and the old notion of he ship-worm (which Linnæus justly called "*Calamitas Navium*") having been introduced into Europe from the Indies was contrary to fact as well as theory, because no "littoral" species belonging to tropical seas has ever been found living in the northern hemisphere, or *vice versâ*. It is true that some species have been occasionally imported into this and other countries in ships' bottoms, and that others occur in wood which has been wafted thither by the Gulf and other oceanic currents; but the former cases belong to littoral species, and never survive their removal, while the latter may be said to be almost cosmopolite. Every species of *Teredo* has its own peculiar tube, valves, and pair of "pallets," the latter serving the office of opercula, and by their means the animal is able at will to close completely the entrance or mouth of the tube, and thus prevent the intrusion of crustacean and annelidan foes. The length of the tube is, of course, equal to that of the animal, which is attached to it by strong muscles in the palletal ring, and varies in the different species from three inches, or even less, to as many feet. The internal entrance or throat of the tube is also distinguishable in each species by its peculiar transverse laminæ, and it has frequently a longitudinal siphonal ridge. Monstrosities occasionally occur in the valves and pallets; and in one instance the pallet-stalk is double, showing a partial redundancy of organs, as exemplified by the author with respect to the operculum of the common whelk. More than one species often inhabit the same piece of wood; and want of sufficient care by naturalists in extracting the valves with their proper tubes and pallets may account in a great measure for the confusion which exists in public and private collections, and which has thence found its way into systematic works. The *Teredines* have many natural enemies. In the South of Italy, and on the North African coast, they are esteemed as human food. In Great Britain and Ireland, four species occur in fixed wood, and eleven others in drift wood, the latter being occasional visitants. Of these, no less than six have never yet been described, and two others are now, for the first time, noticed as British. The number of recorded exotic species only amounts to six more, making a total of twenty-one; but it is probable that, when the subject has been more investigated, a considerable addition will be made to this number.

Mr. Jeffreys then explained the distribution of the littoral species on the shores of Great Britain and Ireland, and produced a synoptical list with descriptions of the new species. He believed all the *Teredines* were marine, except, possibly, Adanson's Senegal species, and one which had lately been found in the River Ganges, the water of which is fresh for about eighteen hours out of the twenty-four, and brackish during the rest of the day; but as a well-known exception of the same kind occurs in a genus of marine shells (*Arca*), and the transition from fresh to brackish, and thence to salt water, is very gradual, such exceptions should not be regarded with suspicion or surprise. He concluded this part of the subject by exhibiting some drawings and specimens, and acknowledging his obligations to Dr. Lukis and other scientific friends.

He afterwards treated the subject in an economical point of view, and remarked that, although the French Government had issued two commissions at different times, and the Dutch Government had lately published the report of another commission, which was appointed to inquire into the mode of preventing the ravages of the *Teredo* in the ships and harbours of those countries, our own Government had done nothing. He alluded to the numerous and various remedies which had been proposed, during the last two or three centuries from time to time, some of which were very absurd; but he was of opinion, from a study of the creature's habits, that the most effectual preventive would be a siliceous or mineral composition, like that which has been proposed by Prof. Ansted for coating the decomposing stones of our new Houses of Parliament, or simply a thick coat of tar or paint, continually applied, which would not only destroy any adult ship-worms then living in the wood, but prevent the ingress of the fry. The *Teredo* never commences perforation except in the larval state*.

A Committee of the Association was formed, at the suggestion of Mr. Jeffreys, to inquire and report as to the best mode of preventing the ravages of *Teredo* and other animals in our ships and harbours.

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* See also Papers by Mr. Jeffreys on this subject in the 'Annals of Natural History' for August and October 1860.

Dr. LANKESTER called attention to the completion of the first part of Mr. Blackwall's work on British Spiders,—a copy of which he placed on the table. The work contains twelve coloured plates, and is one of the most complete monographs hitherto published of the class of animals to which it is devoted. It forms the Ray Society's volume for 1859.

On the Statistics of the Herring Fishery. *By* CHARLES W. PEACH.

On Cydippe. *By* JOHN PRICE, *Chester.*

I will only remind my fellow-naturalists that the *Cydippe* (which has been, like everything else, retarded by this cold season) was pretty abundant in the Mersey on the 16th of June, and may therefore be looked for confidently on the coast henceforward.

In order to enjoy the sight of this most enchanting Oceanid, I advise them—

1. To provide tall glass jars, or, *faute de mieux*, the largest size of "sample bottles," *quite* transparent, and with large mouths. The last can be taken to the shore in a frame like a cruet stand to hold several bottles, *corked during carriage*.

2. To catch the animals in some cup or ladle large enough to take up a *gill* of water with them, to prevent damage. Best of all, in a ¾ spherical ladle, with *tubular* handle.

In either case, plunge it in a *full inch* in *advance* of the *swimming* Cydippe, *to save the trains*, which *easily break*.

3. To keep them, when transferred to their permanent lodging-jar, glass or "*Aquarium*," as *cold* as possible; and *never* (except when examining them) in a *full* light.

4. To watch minutely for the *ova* (grey specks smaller than "Noctilucæ") floating near the surface; and ladle them out (say with a salt-spoon) as *most interesting* microscopic objects before and after hatching.

5. To microscope, with a *low power*, Cydippes containing *food*; easily known, as they are transparent. And if you get the *right kind* of prawn, they will capture and swallow *them*, but not *shrimps*.

6. If Beroes are to be had, and Cydippes are "as plenty as blackberries," remember that the *latter* are the natural food of the former, who will bolt as many as five, one after the other.

7. By *uniting* the two last hints, my curious friends may see, by virtue of the transparency of *both* animals, two digestions going on (*for a short time*) at once. The Cydippe digests the prawn, whilst the Beroe digests the Cydippe. Qu. *Inges*tion?, *Di*gestion?, *In*digestion?.

8. To remember that a number of these creatures were kept in the "good old times" for 13 weeks, without plants, and only changing the water occasionally; that these perished after all by *mere accident*, and that it is the pleasing duty of the rising generation to keep them *all the year round* under the *improved régime*.

On the Aspergillum *or Watering-pot Mollusk.*
By LOVELL REEVE, *F.L.S., F.G.S.*

The *Aspergillum* is a siphoned bivalve mollusk which ceases in an early stage of its existence to live free, and while yet no more than the eighth of an inch in length, sinks into the sand, or adheres to shell or stone, and directs its calcifying functions to the formation of a comparatively large tubular sheath. Upwards the sheath enlarges with the growth of the siphons for their special protection; downwards the animal closes in the sheath by a disc like the rose of a watering-pot, fissured and perforated and bordered by a frill of small tubes. The mantle of the animal, which has been observed once, and only once, on the shores of the Red Sea, enlarges on commencing its sheath growth, and a number of tentacles are emitted, each corresponding with a perforation or tube of the disc. Frequent distortion is imparted to the shell, more especially to the disc end of it, the seat of the mollusk, according to the circumstances of its place of habitation; and when adhering to shell or stone the disc may be scarcely recognizable. Shells with the strength of growth even of *Spondylus*, become distorted by their inability to contend against the outward pressure of foreign bodies. Shells, therefore, of the delicate and comparatively fragile growth of *Aspergillum* would be liable to extreme contortion. *Aspergillum vaginiferum*, inhabiting the shores of the Red Sea, sinks into the sand, as may be seen by the particles of sand and shell *débris* that become agglutinated to the sheath, to the depth of eight to twelve inches and more; the sheath is comparatively straight and symmetrical, and the protruding end becomes furbelowed. A season of rest ensues, another effort is made to extend the sheath, but the calcifying functions either have done their part, or are enfeebled. A little is added to the sheath, and the end is again furbelowed; and in some specimens the process has been as many as eight times repeated.

In adherent species, only one of which, *A. Strangei*, inhabiting the shores of N.E. Australia, has been discovered, the disc is very much pressed in. Two specimens only have been collected, one affixed to the inner cleft of a mussel hinge, and one attached to stone. The peculiarity of this form of *Aspergillum* is that the sheath is formed in a square, and being formed, not in sand, but free, is tortuous and enveloped by a slight periostracum.

Dr. Gray has stated his opinion in a recent memoir in the 'Proceedings of the Zoological Society,' that the sheath of *A. Strangei* is an enlargement of the primitive pair of valves, and that it differs in this respect from the rest of the *Aspergilla*. I incline to dissent from this opinion. Whether by a stretch of induction it be regarded as an enlargement of the primitive valves, or not, the relation between them I hold to be the same in the sand-inhabiting species, as in the adherent species. Dr. Gray also draws a distinction between species which have a wavy depression in the sheath around the circumference of the valves, regarding the wavy depression as a part of the valves, of which only the umbones are seen. My own view is that at the time of the metamorphosis of the mollusk, the valves are not larger in any species than are defined by the smaller outline. When it is considered that the valves are discarded at this time, but not entirely, inasmuch as they are appropriated as material for a nucleus from which to develope a sheath, it is only reasonable to suppose that the new sheath matter would, in some species, obtain a wavy deposit corresponding with the outline of the nucleus.

Remarks on the Geographical Distribution of recent Terrestrial Vertebrata.

By P. L. Sclater, *M.A., Ph.D., Sec.Z.S.*

After enunciating the principles of the distribution of organic beings according to certain laws, independent of the influences of climate and other external conditions, and that of the "continuity" of generic areas, which might, as a general rule, be extended to all natural groups, small and large, the author proceeded to point out what appeared to be the most natural primary divisions of the earth's surface, as deducible from a careful study of the distribution of the terrestrial vertebrates. These were:—

1. The *Palæarctic Region*, embracing Europe, Asia north of the Himalayas, and a strip of Africa north of the Atlas.
2. The *Æthiopian Region*, embracing Africa inclusive of Madagascar, and Arabia.
3. The *Indian Region*, including Southern continental Asia, Sumatra, Borneo, Java, and other islands down to the Straits of Macassar.
4. The *Australian Region*, including New Guinea and adjoining islands, Australia, New Zealand, and Pacific Islands.
5. The *Nearctic Region*, including America down to the Southern limits of the Mexican Table-land.
6. The *Neotropical Region*, including the rest of the New World and the West India Islands.

These Regions were well characterized by their striking zoological peculiarities, as shown by the preponderance of certain types and the absence of others in each; and by the fact that many of the families, more of the genera, and nearly all the species found in each were as a general rule distinct, of which numerous examples were given. These greater divisions of the earth's surface or regions were subdivisible into lesser areas or provinces, characterized by being the abode of distinct species, which in many cases represented one another in their different localities.

An inquiry into the meaning of these laws of geographical distribution was then entered upon, and the question asked, whether it was possible in the present state of our knowledge of the subject to arrive at any explanation of them. It was remarked that the only hypothesis yet put forward which would explain these laws, was that of "genetic relationship" between species or their descent from a common ancestral form. It was an acknowledged fact that the best naturalists were at issue as to the precise limits between representative species and local varieties. It was generally allowed that the latter were descendants of a common progenitor, and the reasons given for the belief in the case of "local varieties" might be shown to be equally applicable to "representative species." Specific differences being once granted to have originated from natural causes, it would be impossible to stop here, and it must follow that greater divergences may have resulted from the operation of similar agents acting through longer periods of time.

On some Peculiar Forms amongst the Micro-Lepidopterous Larvæ.
By H. T. STAINTON, *F.L.S.*

It is well known that the normal form of a Lepidopterous larva is a cylinder, flattened beneath, and slightly tapering and rounded at each end. To this, the typical form of a Lepidopterous larva, we have abundant exceptions in most groups; thus we have the woodlouse-shaped larvæ amongst the butterflies, and again amongst the Bombycina; and in the latter group we have also numerous instances of larvæ adorned with humps or large protuberances on several of the segments, and in some of the Noctuæ larvæ we observe a protuberance on the eleventh segment.

The normal number of legs is sixteen, that is, six true legs and ten prolegs; but two of the latter are wanting in some of the Bombycina and in some of the Noctuina, and in the whole group of the Geometrina from four to six of the prolegs are wanting.

In the group of the Torticina there are very few deviations from the typical form of the larva; but amongst the Tineina we find many genera which give instances of very considerable deviation from the regular cylindric form.

Among the most curious forms in this family, the larvæ of the genus ***Phyllocnistis*** may be mentioned; in these the hinder extremity is so drawn out that it reminds us of the rat-tailed larvæ amongst the Diptera, though the object of the prolonged tail in the ***Phyllocnistis*** larvæ is very different. These larvæ are also perfectly apodal, and the structure of the mouth is peculiar: the jaws of all other Lepidopterous larvæ terminate in two sharp-pointed mandibles; the mandibles of a ***Phyllocnistis*** are perfectly blunt and rounded, like the points of lace-scissors. The reason of this singular formation is pretty evident; the larvæ of the genera ***Coleophora*** and ***Lithocolletis,*** which mine in the interior of leaves, feed on the parenchyma, which they detach piece by piece by their sharp mandibles and swallow; but the larvæ of ***Phyllocnistis,*** though feeding beneath the cuticle of the leaf, do not eat the parenchyma, and a leaf eaten by one of these larvæ, if held up to the light, shows no trace of the attacks of the larva. On what then do they subsist? The larvæ mine rather rapidly forwards beneath the cuticle, raising the cuticle from the epidermis, and they apparently devour something which they find between the two, which, as they do not seem to remove any solid matter of the leaf, must be of a juicy nature. It is no doubt essential to the comfort of these larvæ that the cuticle should not remain detached from the parenchyma in those parts of the leaf which the larva has passed over, and accordingly we find that the cuticle again becomes attached to the parenchyma immediately behind the larva, and that the cuticle may be let down gradually and gently is, I believe, the cause of the prolonged attenuated tail. The object of the blunt mandibles, in like manner, appears to be to avoid any risk of the larva piercing the cuticle, which by letting in the external air would probably be fatal to the existence of the larva, as these larvæ have to move their jaws in constant juxtaposition to the cuticle, which, in the aspen tree (which is frequented by the commonest species of the genus, *P. suffusella*), is remarkably thin; it must be a great convenience to the larva that the structure of its jaws is such that it can eat its fill without any danger of piercing the cuticle. Sharp-pointed jaws are necessary to a larva which feeds on the harder parts of leaves; but to this, which only, as it were, sucks up the juice, sharp-pointed jaws are quite unnecessary.

If a leaf eaten by this larva be held to the light no symptoms of its operations will be apparent; but if, instead of holding the leaf between us and the light, we look down on it slantways, we shall perceive some slightly iridescent tracks, which have very much the appearance as though a snail had been crawling across the leaf.

Another peculiarity of this larva is that it never moults; its skin is apparently of so elastic a nature, that it grows with the larva; most larvæ cast their skins four or five times in the course of their lives, but this larva never once undergoes that operation. Besides this, it never sleeps; most larvæ, after enjoying a hearty meal, may be found inactive and inert, in a position which conveys to us precisely the idea of sleep, but a *Phyllocnistis* larva never sleeps, it is always eating; from its exclusion from the egg to its being full-fed, night or day, its jaws are perpetually at work. This is not true only of the larva of *Phyllocnistis*, it occurs throughout the extensive genus of *Nepticula*. I have had abundant opportunities of observing these larvæ at all hours of the day and night, and, unless they are ill or dying, they are invariably eating. Their jaws have certainly solved the problem of perpetual motion.

Ehrenberg expressed surprise that the Infusoria never sleep; and Owen, after long watching the motions of the Polygastrica, concluded they were generally of the nature of respiratory acts, and not attempts to obtain food or avoid danger. He adds, "Very seldom can they be construed as voluntary, but seem rather to be automatic; governed by the influence of stimuli, within or without the body, not felt but reflected upon the contractile fibre; and therefore are motions which never tire."

But the motions of these small larvæ are certainly not automatic; you frequently see the larva turning its head about from side to side of its mine, as though considering where it should eat a bit next, and immediately it has determined that point it sets to work *with a will*, little indicative of involuntary action.

On the Effect of Temperature and Periodicity on the Development of certain Lepidoptera. By Dr. VERLOREN, *of Utrecht.*

A Table was exhibited showing the period at which the pupæ of the *Sphinx Ligustri* were hatched. From these tables it appeared that the great proportion of the insects was produced in the middle of June, independent of the state of the temperature of the season; and it appeared that in cases where the development of the insects had been retarded beyond the fixed period in one year, they appeared only during the limited period in the succeeding year. The observations had been extended through a number of years, and had enabled Dr. Verloren to establish several other interesting physiological facts connected with the species in question.

Mr. WESTWOOD gave an account of an insect which, on account of its anomalous character, had been referred to three different orders of the class Insecta, and which forms the genus *Acentropus* of Curtis, the type being the *Phryganea nivea* of Oliver, regarded as Trichopterous by Curtis, and as Neuropterous by Stephens: Mr. Westwood had many years ago endeavoured to prove it to be Lepidopterous from a consideration of the structure of the perfect insect alone. The transformations of the species having, however, been recently observed by Mr. Brown of Burton-upon-Trent, the opinion of Mr. Westwood had been fully borne out, as was shown by a series of highly magnified diagrams representing the details of the insect and its metamorphoses, contrasted with those of the orders Trichoptera, Lepidoptera, and Neuroptera. The genus appears to be most nearly allied to the family Crambiæ.

On Mummy Beetles. By J. O. WESTWOOD, *M.A., F.L.S.*

The object of this paper was to show that no change had taken place in the structure and habits of several species of insects during the period which had elapsed since the embalment of the mummies buried in the pyramids of Egypt. A number of species of such insects had been recorded by Latreille in the work upon Egypt by M. Calliand; and Mr. Westwood exhibited species of the genera *Necrobia* and *Dermestes* found within the bodies of mummies by Dr. Pettigrew, and which must have found their way into such bodies during the process of embalment and before the final cere-cloths were applied. These insects were not specifically distinguishable from existing species, although of a somewhat paler colour.

On a Lepidopterous Parasite occurring on the Body of the Fulgora candelaria. *By* J. O. WESTWOOD, *M.A., F.L.S.*

After some general remarks on parasitism, the author gave a detailed account of the occurrence of the larvæ of a species of moth on the body of the firefly (*Fulgora candelaria*), for which the name of *Epipyrops anomala* had been proposed by Mr. Bowring, by whom the transformations of the insect had been observed in China. Not only was the fact of the parasitism of the species as a Lepidopterous insect extremely unusual, but also the circumstance that it was not upon the ligaments of the body that the larva of this moth fed, but evidently upon the white waxy secretion so common amongst the *Fulgoridæ*, with which their abdomens are enveloped, was quite anomalous, although wax-feeding habits were known to occur in the larvæ of the species of wax-moths. The insect in question appeared to belong to the great family Bombycidæ, and specimens were preserved in the British Museum and Hopeian Collection at Oxford.

Notes on Tomopteris onisciformis. *By* Dr. E. PERCEVAL WRIGHT, *A.M. Dub. Oxon., F.L.S., Lecturer on Zoology, Dublin University.*

In the summer of 1858, while investigating with Professor J. Reay Greene of Cork, the marine zoology of the south-west coast of Ireland, I had an opportunity of examining somewhat in detail the structure of that puzzling little annulose animal, called *Tomopteris onisciformis.* The tidal current sets in very strongly from the Atlantic into the narrow entrance between Bere Island and the main land, and carries along with it, in the summer season, whole fleets of oceanic swimming creatures. The number of naked-eyed Medusæ and free Actinozoans is almost pass belief to those who have not witnessed similar phenomena. Various little bays with hollow caverns line the sides of this channel, and in these the water lies very still and quiet; here, too, vast numbers of the ocean swimmers congregate, imparting to the water almost a milky hue, which sometimes changes and presents an appearance as if oil had been cast upon it, owing to the highly prismatic colouring of the various Beroes, Æquoreas, Cydippes, &c. A retired nook of this sort is a very paradise to the marine explorer, and such were to us places of very frequent resort. After a little practice, one's eye got accustomed to the varied kinds of locomotion that distinguished more or less each species, so that when I first perceived *T. onisciformis* swimming swiftly with its very peculiar wriggling movements, small as it was, I perceived it to be something new; and a few seconds served to transfer it to a glass collecting-jar. While the whole body was more or less employed, by successive wrigglings, in locomotion, yet it was quite obvious that true locomotion was assisted by the bipinnated series of paddle-shaped organs which are attached at each side of the body. When compared with the graceful floating and umbrella movements of an Æquorea, or the headlong paddle-wheel-like movements of a Beroe or a Cydippe, it could not be truthfully described as graceful; nevertheless, there was something about it very characteristic—something that even seemed to point out its proper natural affinities. One of the little creatures lived in apparently good health with me for about twelve hours, though incarcerated in a small glass jar holding but ten ounces of water; and it would have probably lived longer, but I wanted its tail for examination, and the necessary compression of such an agile and slippery creature between two pieces of thin glass hastened its end. The author then alluded to the papers by Dr. Carpenter, Messrs. Leuckart and Pagenstecher and others on this creature, and gave an outline of its anatomy, alluding to the presence of cilia on the pharyngeal portion, to the peculiar structure of the central portion of the antenna-like organs, to the tail-like extremity, and the presence therein of masses of Spermatozoa; and finally expressed his conviction that there could be no doubt as to its being a complete creature, and that its tail is not a zoold form, as hinted by Dr. Carpenter.

PHYSIOLOGY.

On the Ultimate Arrangement of Nerves in Muscular Tissue. *By* Professor BEALE, *M.B., F.R.S.*

On the Leptocephalidæ. *By* Professor V. CARUS, *Leipzig.*

Dr. Kaup places the European species of this highly interesting family in four generic groups,—*Esunculus, Hyoprorus, Tilurus,* and *Leptocephalus.* It strikes at first, to find amongst the "Apodal" fishes a form with well-developed ventral fins, viz. *Esunculus,* similar to the rest only in its transparency, and in wanting the generative organs, differing from them also in the distinctness of the dorsal and anal. Among the rest there are two well-established genera, *Tilurus* with its hair-like tail, and *Leptocephalus.* According to Dr. Kaup, *Tilurus* contains two species, *trichiurus* and *Rissoi,* but both are probably the same, as *Rissoi* is most likely founded on a mutilated specimen. The chief character is taken from the tail here being shorter; Dr. Kaup adds, however, himself, "perhaps defective in the tail." The species of the genus *Leptocephalus* are to be classed in two groups; the type of the first is *L. Morrisii,* that of the other is *Helmichthys diaphanus* of Rafinesque. The former have the body compressed, the latter rounder, earth-wormlike body. *L. Morrisii* and *L. Spallanzanii* differ only by the height of the former, upon which argument one cannot lay much stress, as exact measurements of many individuals give very considerable differences in the relative height and length of the whole body, as well as of the head and the other parts. The species of the second group, *L. punctatus, diaphanus, Köllikeri, Gegenbauri, Bibroni,* and *Yarrelli,* are representatives of at most two species, *punctatus* and *diaphanus.* The chief distinction is taken from the relative position of the intestinal outlet. I did not find in two specimens out of some dozens the same position of this orifice; nor are the row of black points, which characterize the *L. punctatus,* always so well developed, that they could be taken as a good character. However, the habits differ in some respect from that of the rest. *L. longirostris* reminds of *Hyoprorus*; the latter is probably nothing but a further developed or an earlier form of the *L. longirostris, L. stenops,* and *L. brevirostris*: the two last European species of Dr. Kaup's Synopsis I know only by his figures, but I am very much inclined to believe that they are to be judged like the others.

Taking together the anatomical structure of the whole group, the absence of generative organs, the structure of their skin, their skull, their vertebral column, taking furthermore into consideration the variability of both the zoological characters and the proportional measurements, I cannot but come to the conclusion that all these fishes are nothing but *larval forms* of others. The developed full-grown species to which all of them, except the *Esunculus Costai,* belong, are most likely among the Ophidians, or other compressed forms (*Cepola,* and so on). Although I am not yet able to state with certainty what species or even genera are to be studied in their development as giving Leptocephalideous larvæ, yet I feel quite sure that the family under consideration will ere long be erased from the Systema Naturæ, just as the Ammocœtes has been excluded from the benefit of being reckoned a full-grown member of the Animal family.

On the Value of "Development" in Systematic Zoology and Animal Morphology. *By* Professor V. CARUS, *Leipzig.*

Although there may be some who will object to my bringing forward a topic of general bearing, and who would prefer to have stated some special facts and details new to science, yet I think that meetings of this kind afford the best opportunity of clearing up, or at least recalling to mind, questions which we are all familiar with, the true bearing of which, however, we are very apt to lose sight of. Since Cuvier laid the foundation-stone of our modern classification of animals, there has been within the last thirty-three years much labour bestowed upon the mending his system, and looking for new characters by which his classes and orders may be either altered and arranged in a somewhat different manner, or still better founded. However, we look up to him not only as the reformer of the classificatory branch of zoology, but moreover as the founder of the natural system and of the science of comparative anatomy.

As I intend to inquire into the value of one of the most striking characters of animals with regard to their classification, as well as to their typical organization, I may be allowed to state, first, what is meant by a Systema Animalium, or in other words, what place the classification of animals takes among the branches of zoological inquiry.

We are scarcely aware that we use the word system of animals in quite a different sense from that in which Linnæus used it, and which was intended even by Cuvier when he arranged the animal kingdom anew according to its organization. Even Cuvier compares the system to a great catalogue of animals, in which every single one can easily be found and named. There is, however, one great feature stamped upon all forms of organized beings, which, although implied and even indicated in the system of Cuvier, yet has given to the system of animals quite another aspect,—I mean the *relationship* between different animals. Cuvier, and some later naturalists, and I may say some of the best, considered the system only as a servant to true science. Classification, according to them, is nothing more than, as Stuart Mill says, a contrivance for the best possible ordering of the ideas of objects in our minds, and at most "for causing the ideas to accompany or succeed one another in such a way as shall give us the greatest command over our knowledge already acquired." Although a classification worked out in the most perfect manner in this way must also be one of the aims of our endeavours, yet I may say that our present classificatory inquiries go further. They start from the very fact that the oldest forms, and for this reason the forms nearest to the original creation, do not represent any of those groups of individuals which we are used to call *species*; nor can all of them be classed under the now established genera, families, and orders, but only under the type to which all succeeding species belong. And although we cannot give the direct experimental proof, yet we are bound by logic and by truths forced upon us from all other branches of natural history, to say that these oldest original forms are the primæval forms of all living animals, which originated from them by continued generation and by accommodation to external circumstances continually and progressively changing*. Hereby the general bearing of the system of animals is totally changed. We consider it not only as an arrangement of the animals in such a manner as may help us best in gaining a general view of the animal world, and in placing and finding certain forms of it; but we try to make it the faithful expression of the state of our knowledge respecting the relation of all animals to each other.

Passing from the much spoken of differences between artificial and natural systems, I may only state, that even that arrangement, which is mainly founded on the internal structure of animals, is nothing more than a somewhat modified form of artificial system, taking only one set of properties as basis of the classification. However, it is the best form hitherto proposed, because it takes into consideration more characters than any other arrangement, and leads us naturally forward in the study of animal life. There is as yet one great chasm which severs the classification of minerals from that of animals. In the mineral world we are justified in speaking of species, as the identity of physical and chemical properties grants us the identity of all bodies endowed with these. In the animal world we have nothing but *individuals*, and all sorts of groups are entirely and totally artificial. The law of equal production of like from like through generations and generations, upon which the notion of the species mainly is based, cannot be trusted to, as we have no experience whatever that it holds good for the same animals under different circumstances.

Passing in review the leading characters upon which the different subkingdoms of the animal world are founded, we perceive at once that they change almost in every class. For although the general headings may be taken from the same system of organs, yet the splitting of the classes and orders into minor divisions is dependent on characters especially modified by these very classes and orders. And even here our classification is not quite consistent. Amongst the lower classes of animals, the comparatively simpler organization allows us to take the general form of the bodies as a character to be relied upon, yet no person would be able to call a ctenophorous medusa a radiated animal. Similar instances may be taken from the higher divisions of the animal kingdom; as they are known to all who are familiar with our zoological system, I should go too far if I were to specify what a little attention paid to different orders of animals will tell in a moment. The simple result of carefully looking through the established classes and orders of animals, is that there is only a relative weight to be laid upon the different groups of zoological characters. It depends entirely upon the whole typical organization, and on the correlation of parts as modified by that type. This correlation of parts, which allows us to draw a conclusion from the nature of one organ as to the nature of another, must naturally be changed by the physiological dignity of an organ, which in different types is not always the same; and it will become uncertain whenever the characters which we call specific are becoming indistinct themselves.

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* I first made the foregoing remarks in my 'System of Animal Morphology,' 1853, Introduction.

I thought it necessary to state first in few words, that there is a difference in the value of zoological characters according to different classes, and I am of opinion that the progress of zoology as science depends mainly on the determination of this value in a sharper manner than it has been stated. I published some years ago some general remarks on this subject in a small pamphlet which will scarcely have reached England. Since then my opinion has become still stronger, as I saw that the progress, which zoology owes of late years especially to some eminent British naturalists, was chiefly dependent on the circumstance that the point mentioned was, with or without purpose, taken into consideration.

The structure of animal bodies shows three different relations of complexity; common to all three are these two points; first, that a structure, at first simple, becomes more and more diversified; secondly, that all the differences which appear one after the other make their appearance on a basis fundamentally equal and in itself not changing. They differ according to the difference of this substratum. In one case there is one and the same body changing and becoming more and more complex; in the second case different members of one great fundamental type of organization constitute a series of forms, some less, some more diversified; in the third case the very types themselves are to be regarded as members of one great series, showing less and greater complexity. The practice of scientific inquiry has severed these three different points of view into three different branches of science. The first is the history of development, which may just as well be called the *comparative anatomy of the individual*; the second is the comparative anatomy of the different types; the third is the general morphology of the animal kingdom. These are the three different bearings which animals generally present to the zoologist with regard to their structure. Now we must ask, what use can we make of them, and of the first-mentioned especially? As the zoologist has nothing before him but individuals, it is no wonder that the comparative anatomy of these will throw much light on their nature, their life, and their morphology. As long as it is kept in mind that all the facts of the history of development have relation to the individual, and to nothing else, so long nobody will object to the manner of inquiring, which is quite properly called the genetic method.

All our zoological classification, however, tends toward the establishment of larger groups and types, and here comparative anatomy has its place. It is very significant, that in the Cuvierian system, which we all follow, its later alterations being quite irrelevant to the grand truths upon which it is founded, there is no use whatever made of the history of development, not even in one instance. It has been said that the emendations of this system, and the whole progress of systematic zoology, depend, if not chiefly, yet for a great part, on the employment of the genetic method. On this I may be allowed to make the following remarks. As comparative anatomy rests entirely on the knowledge of the structure of individuals, everything which throws light on the individual will also throw light on comparative anatomy. But with regard to systematic zoology, we have not to deal with larval forms and immature individuals, but only with such as are able to propagate their individual, or if you like it better, specific form. We cannot, of course, put aside all embryological data in our systematic endeavours. However, there is great danger in overrating the help they give us. A system based on anatomy alone is an artificial one, however true it may be; but its value is always great, and the more attention is paid to the physiological and biological bearings of structural facts, the greater will this value be. A classification of animals from embryonic data, however, is still more artificial; it takes only one small group of properties of the animals, and just a group which, by its being confined exclusively to individuals, forbids by itself the taking account of other properties. There are so many striking examples of different development in animals related as nearly as possible, that by these alone the exclusive use of embryology as a basis for classification is defended. And if the fact of frogs developing without the intermediate stages of tadpoles be true (and I have no reason to doubt it), we have in one and the same species differences of development which would in other classes suffice to establish orders. By this very instance it is shown that embryology also has only a relative value as zoological character. Our next inquiry ought to be directed here, as well as in all other cases, towards the establishment of the characteral standard of embryology. Nature herself assists us in the rightly weighing of this character of animal bodies, as almost in all cases it serves only to confirm and strengthen relations which have been found by other methods.

While there is scarcely any difficulty in giving to embryology amongst the other sets of properties its right place with regard to the classification of animals, there is, I should not like to say difficulty, but some seemingly perplexing complexity of phenomena and relations, when we are to make out the true bearing of embryology on *animal morphology*. Here I have to answer two questions: How must we look upon animal forms? and secondly, Are we allowed to explain analogous phenomena by methods not correlate to each other? Animal morphology, as the *science* of animal forms, has to *explain* these, that is to say, to bring them back to *laws*. A law manifested on different forms cannot be that of cause and effect, but only one of a constant repetition of the same phenomena under seemingly different conditions. The object of animal morphology therefore will be to show the constancy with which certain organs appear in certain groups of animals, and to show that the relative position of these organs is always one and the same in the larger and lesser groups. With regard to the first part of these inquiries, there can be no doubt as to the utter failure of embryology. Nothing but a simple anatomical investigation can tell us whether a certain organ or system of organs is present in a certain division of the animal kingdom or absent; and respecting the second part of our morphological researches, I am equally inclined to doubt whether embryology gives us an insight into the anatomical specialities of a somewhat more complex animal by anything else, but by bringing before us certain forms which are not quite as complex as the animal which we dissect. And here we need not take embryological data; we have before us in every type of animals a whole series of more and more diversified forms, which by themselves offer that same series of simpler forms which we find in the individual, and even more clearly manifested, because an embryo is always endowed with certain individual or specific peculiarities, which we cannot at present account for at all. With respect to my second question, the embryologists say that two organs which are developed in two different ways cannot be considered homologous. Now, here I have to give a somewhat similar answer to that which I gave with respect to the embryological classification. The homology of parts is determined by the constant relative position of the organs in one and the same type. An artery which runs up along the mesial line of the cervical vertebræ, is homologically different from an artery which runs along the jugular vein and the pneumogastric nerve. The morphological relations of a certain class cannot be determined but by comparing full-grown individuals, as all the organs do not work to the purpose of these individuals before the development is finished. And in this respect I must deny any influence of embryological researches on morphological questions. There is, however, another set of questions frequently brought before the morphologist, namely, whether two *homologous* organs are developed in the same way. It is easily seen that their homology must have been determined beforehand. It is of course of the greatest interest to know the differences of the development of the same organ in different representatives of the same type. But they show nothing more than the wonderful facility with which Nature arrives at the same results by different ways. They give us additional proofs of that immense richness of means with which the Creator of all animal bodies works out his plans.

On the Deglutition of Alimentary Fluids. By Professor CORBETT, *M.D.*

On the Formation of Sugar and Amyloid Substances in the Animal Economy.
By Dr. ROBERT M^cDONNELL.

After briefly noticing the history of the discovery by Bernard and Hensen of the matter named by the former "glycogene," the writer observed that the term now very generally adopted to indicate this substance, viz. "amyloid matter," seemed in the present state of our knowledge preferable, as it did not involve any theory concerning the ultimate destination of the material in question. It was proposed to embrace under the generic term amyloid substance, two varieties of the starch-like material known to exist in the animal economy, viz. *that of the first species*, or *the amyloid substance of Bernard*, a ternary compound isomeric with dried grape-sugar, convertible by contact with animal ferments into sugar capable of fermenting on the addition of yeast—and *that of the second species*, or *the amyloid substance of Virchow*, a material, which, although in histological characters analogous to cellulose and starch, yet as met with in the prostate gland, spleen, choroid plexus, &c., has not yet been shown to be capable of conversion into sugar undergoing fermentation, and which cannot be considered free from the intimate admixture of azotized matters.

Dr. M^cDonnell discussed at considerable length the question as to whether the liver is endowed with the function of converting its amyloid substance into sugar during life and health, or whether some at least of this substance has not another destination, viz. that of becoming nitrogenized, and thus being, so to speak, raised from the class of ternary to that of quaternary compounds.

Admitting that this is one of the most delicate questions in physiology, and being most unwilling to appear to dogmatize on the subject, the writer detailed a considerable number of experiments on blood drawn from the right side of the heart of animals variously fed, which seem, on the whole, to support the view that transformation into sugar is not the normal destination of the amyloid substance formed in the liver.

An Experimental Inquiry into the Nature of Sleep.
By ARTHUR E. DURHAM.

Contributions to the Theory of Cardiac Inhibition.
By Dr. MICHAEL FOSTER.

On certain Alterations in the Medulla Oblongata in cases of Paralysis.
By ROBERT GARNER, *F.L.S.*

In this paper it was shown, and the fact illustrated by specimens, that in old paralytic cases the crus cerebri on the side of the cerebral lesion and the corresponding anterior column below the pons, but only to the decussation, are both found much atrophied, and this very frequently, though it has been almost entirely overlooked. In such cases the corresponding olivary body retains its plumpness, and these ganglia, therefore, rather appertain to the columns to be seen on the floor of the fourth ventricle, and to the posterior or tegumentary portion of the crura. This connexion may be well seen by tearing down the hardened medulla oblongata through the locus niger, when it will be found that below the pons the posterior torn portion comes forwards and is firmly connected with the olives.

The author appreciates the remarks of Turck and Van der Kolk, and goes on to notice how the olfactory and optic nerves are, in different animals, connected, sometimes with the cerebrum principally, in other cases with the cerebral ganglia, or in others with the medulla oblongata; as they are subservient to the intellectual, the animal, or to the locomotive, respiratory and automatic functions. Some remarks on the origin of a few of the cerebral nerves in animals, and a denial that there is any well-marked distinction of an upper and lower tract in the ganglionic cord of such animals as the scorpion and scolopendra, as indeed was long ago shown in the last animal by Mr. Lord, form the conclusion of the paper.

On the Structure of the Lepadidæ. *By* R. GARNER, *F.L.S.*

In this paper the author bore testimony to the high regard for truth with which Mr. Darwin has recorded his labours, in respect to these animals, though further observation has modified some of his conclusions, and indeed is still wanted.

From finding fragments of shells, small pebbles, &c. in the œsophagus of the *Lepas anatifera*, the author supposes that this part acts as a gizzard, comminuting the food. With Poli he believes in the existence of a heart, situated on the back, a little posterior to the base of the second pair of cirri: however, these observers stand alone with respect to this point. The heart can only be seen in some specimens, according to the state of the tissues, which vary much. It receives its supply at the sides, and gives off vessels before and behind: other large and longitudinal vessels exist.

With respect to the canal running along the abdominal side of the peduncle, and communicating with the body of the animal, on each side, behind the adductor muscle, the author thinks that by means of it the cavity of the prosoma is distended with fluid, thus acting as an antagonist to the adductor, parting a little the shelly valves. The communicating opening lies between the nerves and oviducts as they course between the peduncle and the body.

Mr. Darwin thought that these oviducts conveyed the ova from his ovaries, or the salivary glands of Cuvier, into the peduncle, where ova are found sure enough. But in some specimens, where they are distended with ova, the oviducts are easily traced from the peduncle down into the body of the animal, making a sweep, and apparently ending at the cavities and apertures called acoustic by Mr. Darwin, who informs us that Krohn has also made out this point. The little membranous, buskin-shaped follicle, found in this acoustic cavity, is sometimes wanting.

Cuvier did not often use the microscope, or he would have soon discovered that his so-called ovaries are, in reality, testes.

Little need be said, after Mr. Darwin, respecting the nervous system. The suboral ganglion, besides being connected by a ring with the supra-oral ganglia, supplies the salivary glands, the adductor muscle, the viscera, and the mantle by means of a large anterior branch; also it gives others to the mouth and first cirri, and is connected of course with the chain of ganglia between the other cirri. From the supra-oral pair of ganglia, which are in close apposition, two large nerves (antennary of Mr. D.) go to the peduncle, and two minute twigs to the eye, described exactly in the "Lepadidæ." With respect to this eye Mr. Darwin observes, "in all the genera the double eye is seated deep within the body; it is attached by fibrous tissue to the radiating muscles of the lowest part of the œsophagus, and lies actually on the upper part of the stomach; consequenly a ray of light, to reach the eye, has to pass through the exterior membrane and underlying corium connecting the two scuta, and to penetrate deeply into the body." This is not quite all; the little organ is made perfect in its adaptation, by a small oval or lozenge-shaped transparent spot in these coverings to admit the light, and exactly behind this spot the eyelet may always be easily seen or found. In specimens of *Conchoderma Hunteri*, parasitic on the carapax of a crab from Amoy, this visual organ is situated between the mouth and the adductor.

The so-called proboscis appears to act as an ovipositor, and probably in the prehension of the food. The ova are finally attached to the "ovigerous fræna" as broad sheets, with the assistance of a cement, which sometimes glues them unnaturally together. The fatty matter with which the mantle abounds appears to go to their nutrition, and is apparently taken in at the roots of the fræna. In this mantle, in some species, the young animals are imbedded, and within its cavity impregnation takes place.

The author's specimens of *Lepas* came on shore last January at Kimmeridge, attached in vast quantities to a beam of pine. Some were a foot and a half in length; mostly simple, but others springing one from another. They are tenacious of life, and appear to be generally cast on shore upon our coasts in rough winter weather. The author has had large living *Balani* picked up in the Mersey, and has Lepadidæ attached to nuts of China, the small shells of a Sepia, and minute ones on the shells of *Ianthina* and *Spirula* from the Gulf-weed.

On Saccharine Fermentation within the Female Breast.

By GEORGE D. GIBB, *M.D., M.A., F.G.S.*

After referring to Vogel's discovery of vibriones in human milk, and the suspicion he entertained that their origin was due to fermentation of the milk, but which was denied by subsequent observers, the author proceeded to state that his own researches into this question commenced in the latter part of 1854. At that time an infant seven weeks old was brought to him in the most extreme state of emaciation, whose mother had the appearance of good health. The child, although but skin and bone, was healthy and plump at birth, and was in no way diseased; it had plenty of its mother's milk, but never was satisfied, and seemed ravenous. The most profuse diaphoresis and diuresis had worn it to a shadow. The mother's milk was found to be rich in cream, neutral, sp. gr. 1032, and contained a large quantity of sugar. Examined under the microscope upon the instant of withdrawal from the breast, it revealed numbers of living animalcules, those known as the *Vibrio baculus*, but which he proposed to change to *Vibrio lactis* as more appropriate. These he considered the result of fermentation of the saccharine element within the gland. There was an absence of mammary congestion and heat, which are usually present in such cases, but much general nervous excitement, which it was necessary to control by proper treatment. The child was supplied with an abundance of good cow's milk, and gradually weaned, after the lapse of some weeks, and ultimately completely recovered. The mother's condition also improved; the milk continued to be rich in cream and sugar for some time, varying in sp. gr. from 1032 to 1035, and always neutral; the animalcules remained for some weeks, and finally disappeared; and when drawn from the breast, the milk invariably turned sour much sooner than other examples of cows or healthy human milk.

From 1854 to the present time the author has examined many hundred specimens of human milk, chemically and microscopically, and has occasionally found two species of animalcules to be present in the glands of those whose general health was disordered from various causes during lactation, or where the process of lactation was unusually prolonged, or again, where the quantity of milk secreted was small and insufficient to satisfy the wants of the infant. At early lactation also, where the milk was good and plentiful, but with constitutional symptoms present as already referred to, both species were found, but not in the same individual.

These creatures consisted, first, of the *Vibrio lactis*, resembling little rod or minute hair-shaped bodies, similar to those found in some of the other fluids of the body; and secondly, of *monads*, which he has found to be far more frequent and common than vibriones, and which he proposed to call *Monas lactis*.

Both species were noticed at all periods of lactation, from a few days to upwards of twelve months; the colour and specific gravity of the milk varied, but it was invariably alkaline or neutral. The children were mostly skin and bone, resembling little old men, and soon died of inanition unless other food than the mother's milk was supplied to them. It was not these little bodies that disagreed, but the healthy properties of the milk for assimilation were destroyed, by constitutional causes in the mother, which imparted as it were a galvanic shock through the agency of the uterine nervous system, at the moment of its secretion, giving rise to fermentation in the sugar alone, a substance the author believed the only one likely to produce it within the breast. This process did not necessarily give rise to the formation of lactic acid; had it done so, it would have destroyed the animalcules; moreover, in no single instance was the milk ever found acid. He referred to some experiments of Berthelot to show that fermentation of sugar could take place in alkaline fluids; and the rapidity with which milk containing these animalcules is decomposed and turns sour out of the breast, now generating a large quantity of lactic acid, the author considered a strong proof of fermentation having previously commenced within the breast.

He believed it very probable that the animalcules were generated from the surface of the mucous membrane of the lactiferous tubes, by the fermentation of the sugar at the moment of its secretion from the blood, and this in some cases explained the large numbers present. The necessary connexion subsisting between the mammary glands and uterine organs, explained the influence of the latter in producing the heat and internal congestion of the former by reflex nervous agency, giving rise to the conditions described, in which the vitality of the milk was much impaired.

The author then briefly entered into the general question of treatment to be pursued, both for the parent and child, under the circumstances detailed.

On Asiatic Cholera. By Sir CHARLES GRAY.

A Word on Embryology, with reference to the mutual relations of the Subkingdoms of Animals. By J. REAY GREENE, *B.A., Professor of Natural History in the Queen's College, Cork.*

In a communication bearing the above title, the author endeavoured to explain that any real improvements in the arrangement of the animal kingdom which have been made since the time of Cuvier accorded well with the corresponding advances of comparative embryology. Thus only, indeed, were they shown to be true; for the method of gradations, whatever might be its value in suggesting affinities, could not, of itself, be deemed sufficient to prove them; while its exclusive employment had already, in too many cases, engendered errors, the further multiplication of which could alone be kept in check by a continual appeal to the test of development. From this point of view, the mutual relations of the five sub-kingdoms of animals appear as in the accompanying analytical Table:—

THE ANIMAL KINGDOM.

The organism does not exhibit a division into true layers. Subkingdom 1. PROTOZOA.	A blastoderm is formed, which divides into inner and outer layers.
The two layers of the blastoderm undergo no further fundamental differentiation. There is no distinction into neural and hæmal regions. Subkingdom 2. CŒLENTERATA.	The blastodermal layers become further differentiated. The organism exhibits neural and hæmal regions.
The hæmal region is first developed. There is no segmentation of the blastoderm. Subkingdom 3. MOLLUSCA.	The neural region is first developed.
The blastoderm may become antero-posteriorly segmented, but there is no formation of primitive groove, dorsal and visceral plates*. Subkingdom 4. ANNULOSA.	The blastoderm divides into somatomes. A primitive groove, dorsal and visceral plates are formed. Subkingdom 5. VERTEBRATA.

The generalizations here expressed may, to a certain extent, be regarded as corollaries from the well-known proposition of J. F. Meckel:—d. h. das höhere Thier in seiner Entwickelung dem Wesentlichen nach die unter ihm stehenden, bleibenden Stupen durchläuft, wodurch also die periodischen und Classenverscheidenheiten auf einander zurückgeführt werden†. For a Vertebrate ovum, before segmentation, differs but little, essentially, from an astomatous Protozoon. At a later stage, when the division of the blastoderm into serous and mucous layers has just taken place, it admits of easy comparison with the permanent forms of *Cœlenterata*, the simpler organisms of this group being little more than double-walled sacs of peculiar form, with one extremity open for the purpose of alimentation.

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* This proposition is stated and commented on by Professor Huxley in his recent memoir "On the Agamic Reproduction and Morphology of Aphis." See especially § 5 of the same paper, entitled "The Embryogeny of the Articulata, Mollusca, and Vertebrata compared" (Linn. Trans. vol. xxii.).

† System der vergleichenden Anatomie, Erster Theil, p. 396.

Recent researches on the structure of the *Infusoria* show that some members of that group, for example *Vorticella,* present a more or less obvious differentiation of their primitively homogeneous tissue into imperfect layers. A mouth, also, is constantly present. In these characters the higher *Protozoa* pre-indicate, as it were, certain structural features which are seldom absent among the members of other sub-kingdoms. So also do the more advanced *Cœlenterata,* and especially the *Ctenophora,* foreshadow, in a manner, the anatomical peculiarities of some of the higher types.

All this may be admitted as true, without in any way neglecting the fundamental distinction insisted on by Von Baer between the grade of development and the type of organization.

It is to be observed with reference to the *Annulosa,* that the difficulty of enunciating propositions which shall be equally applicable to the *Articulata* properly so called (*Arthropoda*), and those lower annulose forms known collectively as *Annuloida* or *Vermes,* is still so much felt, as to render it doubtful whether these two great divisions should not be raised to the rank of separate subkingdoms. This, at present perhaps the most important question in systematic zoology, has already been answered in the affirmative by J. V. Carus, Gegenbaur, R. Leuckart, Siebold, and Vogt.

The three first-mentioned of these naturalists regard the *Echinodermata* as constituting a seventh subkingdom. Of the propriety of separating this group from the *Cœlenterata* no doubt can any longer be entertained, although Prof. Milne-Edwards and a few other zoologists of repute still continue to unite these widely different forms under the old name of *Radiata.* So long, however, as the arguments brought forward by Prof. Huxley remain unanswered, the author can see no reason to dissent from his conclusion, that the *Echinodermata,* while forming a distinctly circumscribed *class,* are nevertheless connected by true affinities with the division *Annuloida.*

On the Mode of Death by Aconite.

By EDWARD R. HARVEY, *M.A., B.M., Oxon.*

Death by aconite has been attributed by different observers to its influence upon each of the three vital organs, the heart, lungs, and brain. The following experiments were made with a view of determining, if possible, the organ whose functions were most directly interfered with by the poison. Fleming's tincture was always used. In experiment 1, two minims of the tincture were injected beneath the skin of a dog. In 2¾ hours after injection the dog died. There had been no convulsions, no loss of consciousness, no apparent loss of sight, no change in the pupils, and no disturbance of the respiration: the two marked symptoms were vomiting and great prostration. On examination after death, the veins of the neck were seen to be enormously distended. The heart contained blood partially clotted in both auricles. The other organs were healthy. In experiment 2. on a rabbit, the heart was the organ first affected (its pulsations falling in 5 minutes from 140 in a minute to 100, and soon becoming laboured and irregular); the breathing then became distressed, and just before death there were convulsions. Post-mortem examination directly after death:—The veins of the neck and brain were distended with blood. The heart gave, when exposed, two very slight quiverings, not to be called contractions; all the cavities contained blood. The other organs were healthy. In experiment 3, similar symptoms during life and appearances after death were observed. Experiment 4. The heart of a frog having been exposed by removal of a portion of the sternum, the pulsations numbered 60 in a minute, and were forcible and irregular. After three or four drops of the tincture had been let fall into the thoracic cavity, the pulsations became very rapid, feeble, and irregular, and soon could no longer be felt: the beating here ceased: 10 minutes after death the heart was again pulsating, though much more feebly than in another frog killed by pithing. Experiment 5. A young rabbit was killed by aconite, and another young one by a blow behind the ears. In the animal killed by aconite, there was a slight fluttering movement of the heart, but there were no regular contractions, and galvanism produced no effect whatever; in the other rabbit, the heart was contracting regularly after death; and when all contraction had ceased, galvanism occasioned slight but decided contractions. Experiment 6. Five minims of the tincture were injected beneath the skin of a rabbit. In 40 minutes the pulse was intermittent, and had fallen from 168 in a minute to 36. The temperature within the ears, which at the time of injection was 97°, was 93°. The animal at this time was extremely weak, and unwilling to move; twenty minutes later it was more lively; the pulse beat 60 in a minute, and the temperature within the ears was 96°. The heart's pulsation slowly and steadily increased, and the animal recovered. Experiment 7. In a very young rabbit which received beneath the skin four minims of the tincture, similar symptoms terminated in recovery. In the latter case the temperature fell from 97° to 89°. In each case the only sign of cerebral disturbance was an extreme weakness of the hind legs, which perhaps amounted to temporary paralysis; the breathing was never distressed, and but little hurried. Loss of power of the heart and of the muscles generally, with a fall of temperature, was the marked symptom, and the condition of the animals improved or deteriorated coincidently with the state of the heart. Experiments 8 and 9. In two rabbits poisoned by aconite the heart and large veins were distended with blood. In experiment 10, where there had been during life no symptoms of asphyxia, the right side of the heart alone contained clots; a little liquid blood escaped from both ventricles. This is the only evidence throughout the experiments of death from asphyxia. With this exception, all the preceding experiments led to the conclusion that aconite kills by its action upon the heart, and that the disorder of the brain and lungs, when present, is due to the congestion consequent upon the heart's failure. To discover if the circulation was affected by the outward application of the tincture to an inflamed part, a frog's web was placed under the microscope, and inflammation excited by a little mustard; the whole web was then moistened with a few drops of the tincture; no effect whatever was observed for two hours during which the web was under the microscope. It remained to be seen if the poison acted directly upon the muscles or nerves. For this purpose experiments were made upon frogs: galvanism was applied under various circumstances, and though the experiments were not sufficiently numerous to decide the point, the conclusion arrived at was, that aconite acts immediately upon the nerves, and through them upon the muscles—the heart among the number—and that that organ is the first of the vital organs whose function is interrupted. The latter experiment will be repeated, as well as others which have been instituted on the antidotes of aconite.

Several very careful analyses of the blood and urine of animals under aconite were made, but beyond the increased quantity of urine, nothing worthy of particular comment was discovered.

On the Anatomy of Stenops Potto, Perodicticus Geoffroyi *of Bennett.*

By Professor Van der Hoeven.

It is not for the first time that I make a communication on this species to the British Association (see Report of the British Association for 1850, Trans. Sect., p. 125*). On a former occasion I proved that this species, first described, or rather commemorated, at the beginning of the foregoing century, by Bosman, in his Dutch work on the coast of Guinea, belongs to the group of the genus *Stenops* of Illiger or *Nycticebus* of Geoffroy. I have now the pleasure of bringing here to the meeting a nearly complete anatomical monograph of this species. It was in the beginning of 1857 that I received two well-preserved male specimens of the Potto, presented to me by a Surgeon in the service of the army of the Netherlands, then residing at George d'Elmina. I placed them in the hands of a Candidate of Medicine, F. A. W. van Campen, to procure him a good argument for his dissertation. That able young man, who had devoted himself to the study of anatomy, died before he could obtain his degrees. I received his notes and wrote after them the Monograph, which was edited in 1859 by the Royal Academy of Sciences of the Netherlands in its seventh volume (Ortleedkundig Ondersoek van der Potto van Bosman door F. A. W. van Campen, Med. Cand. Uit zesse nagelasen aanseekeningen byeen gebragt door J. van der Hoeven (Met due Platen Amsterdam, 4to, 77 pp.). Except the female organs of generation, a species, scarcely known thirty years ago, is now more completely investigated than many species of the mammalia living in Europe.

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* In the few lines inserted at that page the name *Lemur Pollo* occurs twice, but is a misprint for *Lemur Potto*. I avail myself of this opportunity to correct another fault, not of the printer, but of myself. The late excellent zoologist E. T. Bennett has not stated in his description of the *Perodicticus* (Proceedings of the Zoological Society, part 1. 1830, pp. 109, 110) that the tarsus was elongated. For the words, "The tarsal bones were of the same shape as in *Stenops*, and the statement of Bennett, that the tarsus was elongated, is incorrect" read "The tarsal bones were of the same shape also **in** *Stenops*, and my former opinion, that the tarsus was elongated, is incorrect."

The little but very natural group of Mammalia called *Lemuridæ*, is one with whose investigation I have been often and at different times engaged. It is well known that zoologists have given the name of a hand to every extremity in which the thumb is opposable to the other fingers. Some have such only on the posterior extremities, as the opossum (*Didelphis*) of America and the *Chiromys* of Madagascar. Those are called *Pedimana*, or *hind-handed*. Others have this structure both in the anterior and posterior extremities, as in the case in the greatest number of monkeys, and in the lemurs (*Quadrumana*). Man is the only species of the order *Bimana* where the opposable thumb exists on the anterior extremities only. Amongst the *Quadrumana* the Lemuridæ are distinguished by the nail of the second finger of the hind feet, which is erected, compressed and sharp (of a subulate shape), while the other fingers have flat nails. I found that in all the species *the fourth finger, both of the anterior and posterior feet, is the longest*. In the apes, on the contrary, as in most other mammals having five fingers, the third is the longest of all. To those characters, sufficient perhaps for the systematic zoologist, we may add, after what is known by the investigations of Cuvier, Fischer, Meckel, W. Vrolik, Burmeister, A. Smith, Kingma and myself, several anatomical characters, as, for instance, that the lower jaw is divided into two distinct lateral parts (as in many other mammals, but never in the monkeys); that the orbit is not closed by the interposition of the *ala magna ossis sphenoidei* between the malar and frontal bones, so that the *fissura orbitalis inferior* is not distinct from the temporal fossa*; that there exists a flat, membranaceous or aponeurotic tongue-shaped appendage beneath the tongue, terminated in slender slips forming a pectinated tip; that the first pair of cerebral nerves is represented by large *corpora mammillaria*, and that the uterus (in those of which the anatomy is known) has two *cornua*, and not that pyriform shape which it assumes in the monkeys and in woman.

The whole group is confined to the eastern hemisphere of our planet. The greatest number of species lives only in Madagascar; some are found on the continent of Africa in tropical regions; and some in East India, chiefly in the isles at the south and east coast of Asia.

I distinguish the *Lemurina* into two groups. In the first there is only one nail of the hinder feet erected and subulate; in the other, not only the second, but also the third has that shape. To this second group belongs only the genus *Tarsius*, living in Celebes, Borneo, and the Philippine Isles. It seems not to be proved that there is more than one species of that genus. The tarsus is very elongated.

To the first group belong all the other *Lemurina*. In those the superior incisors are placed by two pairs, and a vacant space is left between them in the middle†. Some of those have the tarsal bones elongated like *Tarsius*; the calcaneum and navicular bone forming two slender elongated bones placed near each other like the radius and ulna in our fore-arm. This genus is *Otolicnus* or *Galago*. In others the tarsus is not elongated. Some have only two incisors in the lower jaw (*Lichanotus, Propithecus*); others have four in both jaws. To this last subdivision belong the genus *Lemur* (*stricto sensu*) and *Stenops*. The first has a long tail, the second a short, or only rudimental tail, or no tail at all. The last is the case in the slender and small Ceylonese species (*Stenops gracilis*). *All species of* Stenops *have a short index to the fore-hand*; in *Stenops Potto* there is an exaggeration of this generic peculiarity, and the index has only two phalanges. The species is further distinguished by the peculiarity that some spinous processes of the neck, covered only by a thin corneous epiderm, pierce through the fur like prickles. They are those of the fifth to the last cervical, and of the first two dorsal vertebræ.

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* In *Tarsius* the orbit appears to be closed behind, but the deviation from the other *Lemuridæ* is more apparent than real; the great ala of the sphenoid bone is not concerned in the formation of the hind wall of the orbit, but the malar bone is enlarged.

† *Propithecus* seems to make an exception, but it is more an apparent than a real one. See Proceedings of the Zoological Society, 1832, p. 21.

Observations on the Teredo navalis, *and the Mischief caused by it in Holland.* *By* Professor VAN DER HOEVEN.

It is well known that the *Teredo* has been greatly destroying the piles which were employed in the construction of the dykes of Holland in the beginning of the preceding century, chiefly in the years from 1730 to1733. Since that period it is scarcely recorded that any mischief has been produced by that bivalve till the year 1827, when in the province of Sealand it again became noxious. But it was chiefly in the years 1858 and 1859 that the species increased very much, and the destruction produced by it was the cause of a committee of members of the Royal Academy of Science being formed, with the view of inquiring concerning the damages in different localities, and as to the best means of protecting timber against their ravages. I have the pleasure to place the Report of those gentlemen, published some weeks before I left Leyden, in the hands of the gentleman who has given such an elaborate dissertation on the Ship-worm to this meeting of the British Association. He will I hope make known hereafter the chief contents to the English naturalist. From the comparison of different records, it seems to result that the species, which it is well known now was not imported from foreign and warmer seas, exists always on our coasts, but that there are some periods of greater occurrence, produced as it seems by high temperature of the year and by dry summers.

Different experiments have proved that some proposed means of preserving timber against the ship-worm are only useful for a short time, or even not useful at all; such are mixtures of fine fragments of broken glass and fat, different oil-paintings and the like; such is also the imbibition with different solutions of salts, sulphate of copper, acetate of lead, and others. The best success, on the contrary, yet obtained was by creosoting timber, a result also obtained in this country, as is stated in the 'Proceedings of the Institution of Civil Engineers.' I think myself fortunate in having the opportunity of placing the book I have brought with me in the hands of a Member of this Association who has such a great knowledge of a subject, to the elucidation of which, in a practical point of view, the Committee of the Academy of Amsterdam has given its conscientious and laborious consideration.

On the Development of Pyrosoma. *By* Professor HUXLEY, *F.R.S.*

On the Nature of Death from the Administration of Anæsthetics, especially Chloroform and Ether, as observed in Hospitals. By CHARLES KIDD, *M.D.*

The author having collected and tabulated 100 deaths from chloroform, 22 from ether, and 2 from amylene, believes himself to be in a position to offer some explanation of these accidents.

Of these 133 deaths, 90 occurred in male patients, and 43, or less than half that number, in females, though anæsthetics have been largely used in midwifery practice. Such occurrences are very rare in children.

From 250,000 to 300,000 operations of all kinds have been performed under the influence of anæsthetics, and chiefly of chloroform, and in some hundreds of severe cases the patient has been more than an hour in a state of deep anæsthesia. In all these latter cases not a single well-attested instance is on record in which death has taken place from simple stoppage of the functions of life, or narcotism of the system by the chloroform. Fully 80 per cent. of all the deaths, and nearly all those from chloroform, have occurred from trivial operations, from very small doses, and *sudden*[illegible] *Pot*[illegible] the anæsthetic had produced its full effect. The author does not c[illegible], but of myself. [illegible]eath cannot occur in the human subject from long-con- [illegible]cription of the *Perodicti*[illegible]hloroform, but only that it has not been observed to do so that the tarsus was elong[illegible] seems probable that when anæsthesia is once established in in *Stenops*, and the state[illegible]nject, respiratory action is diminished, and the breathing " The tarsal bones were of [illegible]eeds on [illegible] diminished scale, almost as it does in the case tarsus was elongated, is inco of hybernating mammals. On the other hand, if respiration by fresh pungent chloroform, vomited matter, &c., be disturbed, slight spasm of the glottis may take place through the recurrent laryngeal nerves. This occurs occasionally in strong and healthy, but nervous subjects, and especially in trivial cases; and the occurrence of death in such instances from a few drops of chloroform is to be attributed to this disturbance and stoppage of the respiratory muscles at the end of the irritant or second stage—this being the dangerous point in administration of chloroform. It may be considered almost as an established law, that patients suffering under old disease and severe nervous irritation or neuralgic pain bear chloroform best.

Dr. Kidd thinks that statistics for future use ought to be examined in two ways: first inductively, and then by comparing the several groups of facts collected, and deducing from them conclusions applicable to practice. Single "positive instances" lead only to false conclusions. Though a single instance in a case of pure physical science may be all that is requisite, as in the case of measurements of atomic elements, angles, &c., this is not the case in so complicated a matter as the one under discussion, in which it is necessary to generalize, not from single facts, but from a comparison of groups of facts.

In surgical practice under chloroform we have to fear, not so much deep insensibility as the production, first, of apnea from muscular inaction, or spasm of the parts of the neck by irritation of the excito-motor respiratory apparatus. The deaths from chloroform may be proved to be of an accidental character, and many deaths during operations are charged to chloroform which would have occurred equally before chloroform was used, and would then have been put down to some other cause. For instance, of 45 deaths recorded by Dr. Snow, 6 were attributable to fright. Those which really follow chloroform commonly occur *before* the operation, and seldom or never as the result of a long tedious operation: of 85 deaths which have been classified, 9 were cases of delirium tremens, and of the remainder not one followed a capital operation.

The fact also that in 300,000 operations of all kinds chloroform has saved from 6 to 10 per cent. of lives, as held by Prof. Simpson and the author, also tends to prove that the cause of death, at least in hospitals, is of an accidental character. From a general survey of the facts, the author finds that the deaths from chloroform are all sudden, and many of the nature of "fit." Chloroform has a powerful irritant action upon the pneumogastric nerve; and it is found that a similar irritation by electricity causes vomiting and stops the action of the heart. Hence syncope may possibly occur, if this irritation or (tetanoid ?) apnea of the respiratory muscles and laryngeal nerves be reflected to the heart through the cardiac nerves of the same pneumogastric trunk: this mode of death is most remarkable, for instance, under the analogous agent—amylene. The general effect of the introduction of chloroform into surgical practice has been good; and where it acts badly the author believes that the cause may often be found in the tendency in patients themselves to defer submitting to an operation till too late. Upon a comparison of the present surgical death-rate with that of 1846 immediately before the introduction of chloroform, it appears 10 per cent. lower; and further, of the deaths which have taken place, one-fourth have been in persons who have previously taken chloroform without ill effect. Both these facts support the author's view of the accidental nature of death from chloroform.

The fact of death from chloroform occurring in slight operations and early in the administration, has been remarked by all the chief observers, viz. MM. Robert of Paris, Denonvilliers, Paget, Snow, and Brown-Séquard. The opinion that this is due to disease of the heart is erroneous. In most fatal cases the heart has not been found diseased. Thus in 4 cases in London hospitals, the post-mortem examinations of which were attended by the author, the heart-fibres were examined and found healthy, though one of them (at Guy's) was reported in the medical Journals as a marked case of fatty heart. In 18 deaths reported in Journals which presented some visible lesion, 3 only showed diseased heart. Again, in 24 deaths from ether, the cause appears to have been extreme hebitude, muscular relaxation and exhaustion, and in some consequent hæmorrhage following operations.

On the other hand, numerous patients known to have diseased hearts have taken chloroform without any bad result, and in hundreds of animals death has been observed to take place through the respiratory muscles first, the heart suffering as a mere consequence. There have been probably 100 deaths from chloroform, and twice as many patients saved from impending death by the proper use of restoratives, the chief of which is artificial respiration, which "wakes up" the respiratory muscles. These restoratives have been directed so as to excite the reflex and respiratory system of nerves. Some patients have probably been lost by means used on the theory of fatty or obstructed heart. Intoxication, delirium tremens, and hysteria all contraindicate the use of chloroform; and it was also found during the Crimean war, and more recently at three several seats of war in Italy, that nervous frightened prisoners were particularly bad subjects for it. Any condition of violent emotion ("exaltation of sensibility") would appear to approach that state which causes spasm of the glottis, trachelismus, &c., while depressing emotion (fright?) may lead to syncope. Dr. Snow does not seem to have noticed the effect of delirium tremens; but in 85 fatal cases, collected by the author in the hospitals, 9 appear due to it, or to intoxication; the mischief is probably owing to the cerebral hemispheres, medulla, and reflex system in the spinal cord being weakened by alcohol. In 4 well-authenticated cases the heart was still beating after respiration had ceased; this is also very often seen in experiments on animals; and probably observation only is wanting to establish the more frequent occurrence of this phenomenon in man. In the author's opinion the heart is one of the *very last organs* which is depressed by chloroform, and this fact it is which renders its use comparatively safe. He fears rather the implication of the "respiratory tract." The chief conclusions at which Dr. Kidd arrives are as follows:—

1. Ether is little if at all superior to chloroform. In "ether mixtures" the ether is first inhaled pure. Ether causes the pulse to intermit, and is to be avoided where we fear excessive hæmorrhage or muscular relaxation; but in dislocations and in midwifery it has some points in its favour, but not in a mixture with chloroform. Ether, too, in a sick room may take fire, but chloroform does not.

2. There is less reason to fear the effect of anæsthetics in women and children and in severe operations, than on robust men; especially if given to the use of intoxicating liquors, or when the operation is connected with tendinous parts, in which cases syncope often follows when no chloroform is used.

3. Hospital experience tends to prove that chloroform is less dangerous in proportion as the operation for which it is used is more severe. When once the palpebral conjunctiva is insensible, there is a period of safety during which the respiratory action is diminished like that of hybernating mammals; the heart remains unaffected, but the pulse becomes larger. The many instances in which this has been seen, seem to overpower isolated cases of death from diseased heart and chloroform, and should encourage hopeful views on the use of anæsthetics.

4. Idiosyncrasy has probably little or nothing to do with deaths from anæsthetics, if we omit habits of intoxication, hysteria, and tendency to "fits." Thus repeated trials of chloroform ("*trials d'essai*") on a patient are a mistake, and nowise affect the chance of his safety on any given occasion.

5. There are two, or perhaps three modes in which anæsthetics may cause death, and which require watching. (*a*) Ether may do so at some uncertain interval of time during the first twenty-four hours *after* an operation. (*β*) Chloroform instantly, by an action on the laryngeal-recurrent and double respiratory centre in the pneumogastric nerves. In half these cases, probably, as in apnea or asphyxia, the heart is still beating; and (*γ*) in other cases by syncope (as a coincidence?).

6. In several cases, *e.g.* those of delirium tremens, the death probably occurs because ordinary restoratives fail to act in consequence of the imperfect reflex nervous system; but in cases of impending death, we are to have recourse to artificial respiration by pressure (rather than the Marshall Hall plan), since this also acts upon the engorging cavities of the heart; tracheotomy if we have reason to fear spasm of the glottis or asphyxia; sudden dashing (not too long continued) of cold water; fanning of fresh air on the face, &c.; but as the spasm may subside, we are not to do too much at first. Acupuncture, quickly done, of the muscles of the neck is recommended in order to irritate the spinal accessory and phrenic nerve, but not the eighth pair; and "Faradisation" here also is most valuable.

7. Our experience of oxygen gas, common galvanism, &c. as restoratives is not encouraging at present. Injection of port wine into the rectum is better, or the

transfusion of any simple saline fluid into the veins, as has been tried in the case of animals poisoned with chloroform, and as in the analogous collapse of cholera.

On a Hydro-spirometer. *By* Dr. Lewis.

On the Development of Buccinum. *By* John Lubbock, *F.R.S., F.L.S.*

In the year 1851 MM. Koren and Danielssen published a memoir[*] on the Development of the Eggs of *Buccinum undatum* and *Purpura lapillus*, in which they gave an interesting account of the development of the young mollusks, and especially excited the surprise of naturalists by certain statements regarding the amalgamation of several eggs to form one embryo.

The two above-mentioned species produce peculiar capsules, each containing several hundred eggs. The capsules of *Purpura* are bottle-shaped, those of *Buccinum* are like a round cushion, and are attached to one another in clusters, and fastened to rocks, shells, or sea-weeds. Often, however, they are detached and thrown up on the shore, so that they are familiar to all those who ever walk along the beach near high-water mark. The egg-capsules of *Purpura* are attached singly to the rocks. It was already known that, although each capsule contained a great number of eggs, only a small number of embryos, from fifteen to thirty, came to maturity.

MM. Koren and Danielssen gave a very extraordinary account of the phenomenon. According to them the eggs grouped themselves in masses, round which a common skin was formed, and thus numerous ova combined to form one embryo. This account of a process, so different from that with which we are familiar in other animals, was not likely to pass long without either confirmation or opposition; and accordingly Dr. Carpenter[†], having studied the development of the eggs of *Purpura lapillus*, disputed some of the statements made by MM. Koren and Danielssen, gave a very different explanation of the whole phenomenon, and added the high authority of Messrs. Busk and Huxley in confirmation of his view.

Dr. Carpenter had no opportunity of making any observations on the embryology of *Buccinum*, but he convinced himself that the egg-capsules of *Purpura lapillus* contain two sorts of bodies, namely true eggs and "yolk-spheres," which, however, are at first undistinguishable from one another. After a while, however, "all the egg-like bodies in the capsule begin to show signs of cleavage. In the greater part of them, the two segments produced by the first cleavage are equal, or nearly so; and each of these again subdivides into other two, which are alike equal;" after which the division becomes irregular. These are the so-called "yolk-spheres." Some few of the egg-like bodies, on the contrary, divide into two *unequal* segments. These are the true eggs, and each embryo takes its origin from one of these. The embryo then developes rapidly in itself a central hollow or stomach, a wide œsophagus, and two lobes covered with cilia. It then commences to *swallow* the yolk matter around it, and this is the reason that the number of embryos is so much smaller than that of the egg and yolk-spheres.

MM. Koren and Danielssen by no means gave up their theory, but after repeating their observations, they reiterated their statements[‡], giving, however, it must be confessed, figures much more nearly resembling those of Dr. Carpenter than the ones contained in their first memoir.

Finally, Dr. Carpenter, in the 'Annals and Magazine of Nat. Hist.' for 1857, has published some further remarks on the subject, and adds, in addition, the testimony of Dr. Dyster to the truth of his assertions. This is the present state of the question; and considering how common are the egg-capsules of *Buccinum*, it is remarkable that no one has tested MM. Koren and Danielssen's statements in reference to that genus.

The whole subject is one of great interest; and though I could not doubt the truth of statements made from independent observations by four such excellent authorities as Messrs. Carpenter, Busk, Huxley, and Dyster, yet MM. Koren and

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[*] Bitrag til Pectinibranchiernes Udviklingshistoire. I have not seen the original work but there is a translation of it in the Ann. des Sc. Nat. for 1852.

[†] Quarterly Journal of Microscopical Science, vol. iii. p. 17.

[‡] Fauna Littoralis Norvegiæ, vol. ii.

Danielssen, though wrong as to *Purpura*, might still be quite correct in the case of *Buccinum*, and I was very anxious to repeat their observations. It could not be denied that it was *à priori* probable that what was true of *Purpura*, would also apply to *Buccinum*. Still, if I had any bias, it was in favour of MM. Koren and Danielssen. Many insects present us with a case in many respects parallel. In Lepidoptera, Hymenoptera, Diptera, Neuroptera, and the Geodephagous beetles, each egg is accompanied by several vitelligenous cells, or as we might call them in the words of Dr. Carpenter, yolk-spheres. After a while the walls of the vitelligenous cells disappear, and the whole group unites to form an egg. Here we have undoubtedly a certain similarity with that which, according to MM. Koren and Danielssen, occurs in *Purpura* and *Buccinum*.

Buccinum undatum has been stated * to lay its eggs from the beginning of January to the end of April. On our south coast of England, however, it begins earlier, for I found some fresh ones at Brighton last November. I was not then able to examine them with much care, but in February last I received from Mr. Lloyd two packets of egg-capsules, in which I have succeeded in tracing the development of the embryos.

When I received them, the germinal vesicle had already disappeared, and the eggs consisted of yolk-particles immersed in a viscid substance. According to MM. Koren and Danielssen, each egg is surrounded by a chorion and a vitelline membrane, but I was as little able in the case of *Buccinum*, as Dr. Carpenter was in that of *Purpura*, to discover any trace of these structures; and I think I can safely say, from the appearance of the eggs, and from their behaviour when crushed, that they were surrounded by no definite membrane. Many of the eggs, indeed, resembled MM. Koren and Danielssen's fig. 16 (Ann. des Sc. Nat. 1852, vol. xviii.), in which a thick outer membrane is apparently present; but this arises, as will be presently described, from a condensation of the yolk-particles leaving a clear border of the viscid substance.

The presence of a vitelline membrane certainly seems to me improbable, but about the so-called chorion I am more doubtful. MM. Koren and Danielssen mention (*l. c.* p. 258) that it early disappears, and this may have already taken place in my specimens as well as in those of Dr. Carpenter.

The eggs in my egg-capsules did not coalesce. They collected certainly in a heap, but they remained quite separate from one another, and showed no tendency to unite.

Very few showed any trace of segmentation. In this respect my observations, so far as they go, are quite in accordance with those of MM. Koren and Danielssen. There is, however, always a certain amount of suspicion attached to negative evidence, and it seems *à priori* very improbable that *Purpura* and *Buccinum*, which agree so closely in most points connected with their embryology, should differ in such an important matter.

Dr. Carpenter considers that the capsules of *Purpura* contain two sorts of egg-like bodies, which, however, can be distinguished from one another only by their modes of segmentation.

I was not able to perceive any difference in the eggs of *Buccinum*, except that in some the yolk-granules were condensed, so as to leave a margin of the clear, glairy substance; but it must be remembered that in each capsule only a very few eggs undergo segmentation at one time; and the process appears to be altogether so irregular, that my observations do not enable me to come to any satisfactory conclusion on this point. It would be desirable to investigate the formation of the eggs in the ovary, both of *Buccinum* and *Purpura*, in order to determine whether or no they are all originally alike, and if not, to determine the points of difference.

It would also be well worth while to ascertain the relation which the segmentation of the yolk bears to the development of the embryo.

It is so generally present throughout the animal, and apparently so universal in the Mollusca, that strong evidence would be required to show that *Buccinum* forms any exception to the general rule; and yet, as far as my observations went, the process certainly seemed to be subject to considerable irregularities.

The whole subject of yolk-segmentation is one of great interest.

Among the Entozoa, it appears to occur in certain species of *Strongylus*, *Ascaris*, *Gordius*, *Mermis*, and *Echinorhynchus*, and in *Filaria*, *Filaroides*, and *Sphærularia*.

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* Ann. des Sc. Nat. *l. c.* p. 258.

Van Beneden asserts that it occurs in the Cestoids generally; but this is denied by Kölliker, as far as concerns *Tænia* and *Bothriocephalus*. There is a similar difference of opinion as regards *Cucullanus elegans*, in which species Siebold (misled, according to Kölliker, by the large size of the two primary embryo cells) supposed that there was a true segmentation. The figure given by Kölliker sufficiently explains how such a mistake might have occurred*. Van Beneden also denies that any segmentation occurs in *Echinorhynchus*, a difference of opinion which may have arisen from different species having been examined, since, while segmentation has been observed in *Ascaris nigrovenosa, acuminata, succisa, osculata, labiata, brevicaudata*, &c., it appears, according to Kölliker, to be absent in *Ascaris dentata*. It is evident therefore that this species cannot be naturally included in the same genus as the others, and that the two groups, however similar, are in reality very remote from one another.

Oxyuris ambigua and *Gyrodactylus* have been also asserted to develope without yolk-segmentation, though in the case of the latter there appears to be some doubt.

In the Annelids it has been observed in *Polynoe, Exogone, Clepsine, Nephelis, Protula, Hermella*, &c., and is not known to be absent in any.

It has also been observed in the Tardigradà and in Lacinularia. Among the Articulata, it has been noticed in *Nicothoe* by Van Beneden, in *Diaptomus* and *Cyclops* by Claus (which I also can confirm). On the other hand, in Insects† and Daphnia I have sought for it in vain, and it is unmentioned by Rathke and Heroldt in their works on the development of *Asellus, Oniscus, Astacus*, and the spiders, though in the two latter cases it may perhaps be represented by the dispersion and reunion of the "Keimscheibe."

Among the Mollusca it has been described in *Actæon, Aplysia, Æolidia, Dentalium, Doris, Limax, Limnæa, Planorbis, Teredo, Tergipes, Tritonia*, &c.

Among the Bryozoa it occurs in *Alcyonella*.

In *Salpa* it has been observed by Kölliker, while in *Pyrosoma* it would appear, according to the recent researches of Huxley, to be impossible.

All this, however, is a digression, and I must return to my *Buccinum*.

The egg-capsules were sent to me on the 19th of February, at which date the eggs in most of them were diffuse, though in some they had already begun to collect together. At this time no embryos had appeared. On the 29th the eggs were more closely compacted, and each capsule contained from five to twenty embryos.

The eggs now adhered together in a more or less compact mass, but showed no tendency to amalgamate, and were very easily separable from one another by the point of a needle. Imbedded in and about the mass were the embryos; the smallest consisting apparently only of a clear substance, surrounding the almost unaltered yolk, and having on one side an enormous orifice or mouth leading into a central cavity. The more advanced embryos already showed traces of the ears and the salivary glands, and began to swallow the other eggs whole. In spite of a careful search, I never found any collections of eggs simply surrounded by a membrane, as described by MM. Koren and Danielssen and figured, *l.c.* fig. 17. Embryos containing more than three or four eggs always possessed the salivary glands and auditory organs. Nevertheless, were Messrs. Koren and Danielssen's theory correct, such masses ought to be tolerably frequent.

Nevertheless, the young embryos were so voracious and swallowed so many other eggs that they became greatly distended, and on a superficial view appeared sometimes as in MM. Koren and Danielssen's fig. 17 (Ann. des Sc. Nat. 1852, pl. 5). By turning these over, however, with a little care, the ciliated lobes could always be discovered. At this period also the eggs sometimes adhered together so as to form rounded masses; but in such cases they were quite separate, were surrounded by no membrane, and were easily separable from one another. Nevertheless, if masses such as those described and figured by MM. Koren and Danielssen formed one stage in the normal development, it is very unlikely that I should never have come across a single specimen in this stage.

Moreover, even in the smallest embryos we see already a broad œsophagus, and a mouth so large that a needle can easily be introduced into it. If, however, the increase of size be simply by imbibition through the skin, these would be of no use.

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* Van Beneden appears also to have fallen into the same error. See Mém. sur les Vers Intestinaux, p. 275, 1858.

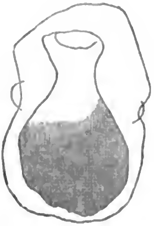
† Leuckart supposed that he had found it in Diptera, but he was doubtless misled by the vitelligenous cells.

Moreover it is very common to see other eggs actually in the œsophagus of the embryos in the act of being swallowed; or we might almost say that an embryo is seldom seen without an egg in its œsophagus. In *Purpura*, according to Dr. Carpenter, the yolk is swallowed particle by particle; in *Buccinum*, on the contrary, the eggs not having undergone any segmentation, are swallowed whole, and the process of deglutition is therefore probably less rapid and more easily seen. The presence of yolk matter in the œsophagus of *Purpura* may also be more plausibly ascribed to accident than in *Buccinum*, where, from the large size of the egg compared to that of the embryo, it cannot take place without a considerable tension of the œsophagus, and the swallowing must therefore apparently be a work of some little difficulty.

M. Milne-Edwards suggests (Ann. des Sc. Nat. *l. c.* p. 26) that the so-called eggs are probably only "des sphères vitellines, dont l'envelope utriculiforme présenté un peu plus de consistance que d'ordinaire, et que, par conséquent, l'agregat dont nait le corps de l'embryon est le résultat du groupement des sphères vitellines d'un seul œuf, et non le produit de la reunion de plusieurs œufs primitivement distincts."

It will be seen, however, from the preceding description, that though M. Milne-Edwards was fully justified in the scepticism with which he regarded the description given by MM. Koren and Danielssen, he was not equally happy in his attempt to explain away the supposed anomaly.

1.



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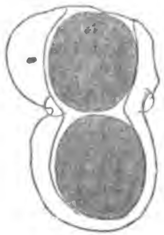

Fig. 1. Embryo in outline, to show the mouth and digestive cavity.
Fig. 2. Young embryo in the act of swallowing an egg.

On the Influence of Systematized Exercise on the Expansion of the Chest.

By ARCHIBALD MACLAREN.

Exercise is the most important agent in physical growth and development, inasmuch as it qualifies the condition, the action and the influence of all the others. This importance is not always appreciated, because the effects of exercise on any part of the body but the muscular system are imperfectly understood. All exercises may be classed under two heads, Recreative and Educational. The first of these embraces all our school games, sports and pastimes,—a most valuable list, but quite insufficient to produce the perfect development of the body:—1st, because the parts of the body chosen to execute the movements of the game are those which can do them best, not those which need the exercise most; 2nd, because it is a distinctive feature in the best and most ardently practised of them, that they give a large share of employment to the lower half of the body, and but little (some not at all) to the upper half; and 3rd, the little which they do give is almost monopolized by the right side. The tendency of these exercises is therefore to develope the lower half of the body to the exclusion of the upper. It must always be remembered that while in developing a limb to its full power and perfect conformation, we do that and nothing more; in developing the trunk of the body, we do that and a great deal more, we directly aid in the development of all the organs which it contains. The point to be desired is the uniform and harmonious development of the entire body; because the strength of a man is but equal to that of his weakest part, while the natural tendency is to gauge and estimate the general strength by the power of the strongest part. This equal development is to be obtained only from systematized exercise, prepared upon a clear comprehension of what is required, and based upon a knowledge of the structure and ascertained functions of the parts of the body to be employed, and of the laws which govern growth and development. The inadequacy of recreative exercise to produce this development is fully borne out by the frames of the youths who yearly arrive in this University from our public schools. As the case now stands, every one who so arrives here does so with the upper part of the body greatly in arrears. So distinctly is it in arrears, that an average of 2 inches in girth of chest is obtainable in the very first term of his practice in the Gymnasium. This rate of increase is not sustained beyond the first term, therefore it must be chiefly expansion of the cavity of the chest; and it must be an arrears of expansion, otherwise it would be sustained, seeing that the process which produced it is increased and accelerated in the advancing courses of exercise. The operations of systematized exercise are equally important and decided in other directions, and especially in the rectification of abnormal spinal developments.

On the Artificial Production of Bone and Osseous Grafts.
By M. OLLIER.

M. Ollier exhibited some specimens illustrating the results of his experiments on the production of bone, and summed up in the following propositions:—

1. When the periosteum is detached from a bone, one end remaining attached, bone is formed in the direction of the periosteum, its form and size being determined by the size and position of the membrane.

2. After union has begun to take place between the periosteum and the soft parts, the pedicel may be divided, but bone will still continue to form.

3. If the periosteum be removed altogether and inserted among the soft parts, it will make an attachment, and bone will be developed.

4. If the inner surface of the periosteum be scraped off in part, no bone will form on the portion so treated.

5. If the matter scraped from the inside of the periosteum be brought into contact with soft parts, bone will be developed from the periosteal cells.

6. If a bone be taken out of its periosteal sheath, new bone will be produced; but if a segment of such sheath be removed, no bone forms in that space.

7. If a bone be removed entire with its periosteum and inserted into soft parts, adhesion will take place, and new bone will be deposited from the periosteum on the old.

8. If, in a piece of inserted bone, a part be deprived of periosteum, that part dies or is absorbed. This latter process may take place by the denuded portion becoming either encysted or subjected to suppuration; as a general rule, in animals that are healthy, and live in the country, the process of encysting takes place; while in feeble animals and those living in towns, suppuration is the ordinary result.

Experiments on Muscular Action from an Electrical point of view.
By Dr. C. B. RADCLIFF.

On the Process of Oxygenation in Animal Bodies.
By B. W. RICHARDSON, *M.A., M.D.*

So soon as the discovery of oxygen by Priestley became an established fact in the world of science, inquiries were set on foot as to the influence of this substance on animal bodies. The term by which it was long known, "vital air," indicates sufficiently the interest that was attached to it in a physiological point of view. Priestley himself made various physiological experiments with oxygen, in which line of research he was followed by Lavoisier, Beddoes, Sir Humphry Davy, Hill, and several other celebrities of the declining eighteenth, and rising nineteenth century. From the researches of various experimentalists, it had been concluded that the inhalation of oxygen in the pure state, by giving rise to a greater absorption of the gas, sets up an increased oxygenation in the body,—hypercausis, and inflammatory conditions, general and local. This view, first promulgated by Dr. Beddoes, and followed up by many contemporary writers, was probably the basis of the chemical nomenclature of disease invented by Baumé, in which disorders were divided into those of oxygenation, of calorification, hydrogenization, azotification, and phosphorization, with remedies of the same names for their treatment.

A second conclusion as to the influence of oxygen on animals, intimated (also from experiment) that oxygen, when inhaled in the pure form, is even less active than as it exists diluted in common air; that, instead of increasing the combustion of the body and its activity, it lessens these, and that animals exposed to it too long die from coma attended with a steady and undiminishing exhaustion. The idea that less oxygen is absorbed when the gas is breathed in the undiluted state was supported by Davy: the statement that the gas destroys by narcotic exhaustion was doubtfully suggested by Priestley, and openly by Broughton. For years this view of the question has been the one most commonly taught in this country.

The last conclusion that had been drawn from experiment relative to the effects of pure oxygen was, that it has no injurious influence on life. Lavoisier, in his later experiments, seems to have drawn this inference, and Regnault has greatly confirmed it.

In 1852, with these conflicting data before him, those of Regnault only excepted, Dr. Richardson commenced an inquiry into the whole subject, which he had continued, with intermissions, to the present time. The author here narrated his earlier experiments, from which he came to the conclusion that animals of active respiration, as dogs, cats, and pigeons, on being subjected to a constant stream of freshly made oxygen, become subject to inflammation, owing to the rapid destruction of the tissues,—hypercausis. In further experiments, he found, however, that his rule was not common to all animals; for rabbits and frogs were kept by him even for weeks in oxygen without apparent injury. On the data, therefore, he gave the following as the first major proposition of his paper:—

The influence of pure oxygen, as an excitant, differs according to the animal; being most marked in animals of quick respiration and high temperature, and least marked or nil in those of feeble respiration and lower temperature.

Up to 1856 the author had felt assured that oxygen, when it destroys life in the actively breathing animals, does so by causing a too rapid oxidation of tissue and the so-called inflammatory process; and he believed that the symptoms of narcotism and paralysis, named by Broughton, were due without doubt to one or other of two possible errors, introduction of carbonic acid, or modifications of the air-pressure exerted on the animal. In 1857 he began to suspect that his view was not strictly correct; but he had no proof either one way or the other until the present year, when a new observation opened a new phase of the question. Having made on one occasion forty gallons of oxygen, and having, by the side of the reservoir containing the oxygen, another reservoir of equal size filled with water, Dr. Richardson determined, in order to economise both labour and material, to collect the oxygen from the supplying reservoir, after it had passed through the chamber containing the animals. He arranged also to wash the oxygen in alkaline solution until it was free of carbonic acid altogether, to pass it over sulphuric acid to remove any ammonia, and finally to charge the second reservoir with it and to use it again, sending it thus backwards and forwards from one reservoir to the other until it was all used.

When the apparatus was complete, he placed four warm-blooded animals, a cat, a dog, a pigeon, and a rabbit, with two frogs, in a large chamber, and at 11 o'clock in the morning commenced the transference of the oxygen, passing it through the chambers at the rate of 2000 cubic inches per hour. In six hours the whole of the primitive oxygen, minus nearly 1000 cubic inches which had been lost in respiration, was transferred into the second reservoir. The gas was now tested, and having been found to give no reaction to lime-water, it was driven back through the chamber and washed again thoroughly with potash, to be received once more into the reservoir number one. As the first charge of oxygen was passing through the chamber, there were exhibited no signs different from those of excitement, which had before been seen; but as the second charge passed through, all the animals became depressed and drowsy. After an interval of four hours, the current was again changed, and the oxygen, purified most carefully of extraneous matter, was a third time given to the animals. It now became more obvious that every animal was under some peculiar depressing influence; even the rabbit did not escape. The symptoms were entirely different from those arising from carbonic acid. The breathing was quick, but easy and tranquil. There was not the slightest approach to convulsion. The pigeon buried its head under its wing, and simply drooped and slept. The four-footed animals sat with their four legs straight and their heads between them, nodding as if in profound and pleasant sleep; they were aroused with difficulty, and fell off again in an instant. Then the fore-legs slowly gave way forward, as if paralysed; and, before the third charge of the oxygen was three parts over, the pigeon was dead, and the kitten was so nearly dead that it was not easy to detect its chest movement; the dog gave no sign of sensibility, but breathed softly; the rabbit was fast asleep. The frogs alone were unaffected.

At this crisis, a little air was pumped out of the chamber through lime-water; it gave less indication of carbonic acid than the common air which the experimentalist was breathing.

The animals were then removed, and a lighted taper was placed in the chamber. The taper burnt with more brilliancy than in the air, but with a slight yellowness of flame.

The animals were all nearly dead. The kitten died a few minutes after removal; the rabbit recovered in two hours; the dog seemed paralysed in the limbs for the greater part of the day, but recovered. When the bodies of the pigeon and the kitten were opened, there was found no indication of asphyxia. The lungs were inflated and red; the heart contained blood on both sides, but the blood in each side was of the same hue, neither being very dark; the brain was bloodless; the other organs were natural. The appearances in the pigeon corresponded with these with the most minute accuracy.

Dr. Richardson next narrated the histories of several other experiments, from which he derived, apparently to demonstration, the following and second major proposition:—Oxygen, when breathed over and over again, although freed entirely from carbonic acid or other known products of respiration, loses its power of supporting life; the process of life ceasing, not from the introduction of a poison, but as by a negation, or a withdrawal of some principle extant in the primitive oxygen, which is essential to life.

The last section of the paper had reference to the influence of oxygen on muscular irritability; and various experiments were again given. On them the author founded the third major proposition.

Oxygen, while it is essential to muscular irritability and muscular power, exerts its influence over muscle, not as a direct excitant of muscular contraction, but by supplying to the muscle an agent or force by which the muscle is fitted for contraction on the application of an exciting cause.

The Action of Tea and Alcohols contrasted. By EDWARD SMITH, *M.D., LL.B., F.R.S., Assistant Physician to the Hospital for Consumption and Diseases of the Chest, Brompton, &c.*

In this paper the author stated the results of a series of original inquiries into the influence of these two substances which appeared in the Philosophical Transactions for 1859.

The general expression of the action of tea is, that it increases all vital actions, and causes the elimination from the body of more material than it supplies.

It *increases* the ease, frequency and depth of respiration, but does not much affect pulsation.

It *increases* the action of the skin, as shown by the increase of perspiration; and as in the conversion of fluid into vapour there is a thousand-fold increase in the absorption of latent heat, perspiration must cool the body.

It *increases*, and does not disturb, nervous, mental and muscular action, and it is not followed by reaction.

Small doses often repeated have fourfold the effect of a large dose.

Large doses cause nausea and narcotism.

The addition of acids and fat, as cream, lessens its action on the skin and increases pulsation.

The addition of an alkali, as soda, increases the action upon the skin and renders it more soothing, but a caustic alkali destroys it.

Hence the author considers that it is inapplicable in the following conditions of the system, viz.:—

In the absence of food (except when a large meal has been recently taken), and therefore at breakfast, unless the system be replete with food, as from a late and large supper. In the ill-fed, and in those of spare habit.

In prison or other dietaries, in which it is a duty not to allow the supply to exceed the real wants of the system, except in the cases in which the powers of assimilation are defective, and then as tea, like other nitrogenous matters, has been shown by the author to promote the assimilation of starchy food, it may prevent the waste of undigested food.

When unusual muscular exertion is made, unless there be also an abundance of food and the skin acting insufficiently.

In those who perspire too easily and profusely.

In low temperatures, except in connexion with abundance of fat, since then the action of the skin should be reduced to a minimum.

In very early life, when all the vital actions are rapidly performed.

He considers also that it is more suited to the following states:—

In the after part of the day, when the powers of assimilation have been shown by him to be enfeebled, and when food has accumulated in the body.

In old persons.

In hot climates, with lessened powers of assimilation; with excess of heat and excess of food.

In those who usually transform food imperfectly.

In those who take too little exercise, and eat too much.

In conditions in which gout is likely to occur.

In those who have the skin inactive.

In all states in which there is excess of food, not, perhaps, in relation to the wants of the system always, but in relation to the power to transform it, and especially where there is excess of heat, as to soldiers on march exposed to the eastern sun.

The author then compared these deductions from science with the actual instinctive habits of mankind in different climates—the test to which all such inquiries must be ultimately subjected—and showed that there is a most striking correspondence, as, for example, the frequent use of tea alone by the sedentary, corpulent, fat and starch-eating Chinese, and, with the addition of an acid, by the industrious poor and exposed classes in that country, and by all classes in the cold of Russia; the addition of milk or cream in our climate; our habit of taking food with tea when we regard it as a meal, and of drinking it *after* dinner in hot weather when we would perspire more freely; the enjoyment of it by the poor, who live chiefly on bread, which is imperfectly digested; and the large appetites of teatotallers.

Hence he was of opinion that tea had a more powerful action upon the body, both for good and evil, than has hitherto been understood, and believed it to demand the regulation which attends the administration of a medicine; and especially urged it to be supplied to soldiers in hot climates, to be drunk cold or hot in small doses during exposure to heat.

In reference to alcohols, the author showed that ales, wines, and spirits differ in their action, not only because they contain varying amounts of alcohol, but have other ingredients, as volatile oils and ethers, salts, gluten and sugar, and thence each must always be discussed separately. He showed that neither the public nor the medical profession substitute a given amount of alcohol and water for these various substances, but admit that each substance has a special action, and that even impurity and newness are held to be deteriorations in any member of the same class.

He showed that all alcohols lessen the action of the skin and increase the force and frequency of the action of the heart, and that these are their true dietetic and medicinal actions.

When the usual dose of a spirit or alcohol was taken duly diluted with water, he had found, by numerous experiments, that the following sequence of phenomena took place:—

1. Upon the heart, probably by the direct contact of the alcohol, and occurring in 2 to 4 minutes.
2. Upon the brain, in from 3 to 7 minutes, as shown by the effect upon consciousness, mental and sensual perceptions.
3. Upon the spinal cord, as shown by lessened tone, lessened power of controlling and lessened desire to use the muscles, a sense of purring through the whole system, and the sensation of heat and cold.
4. Upon the respiratory nervous tract.
5. Upon the secretory (sympathetic nervous) system.

The exhilaration of spirits, accompanied by sense of heat, swelling and redness of the skin, occurred in the first stage, and continued about 30 minutes, and this was changed for taciturnity, chilliness, and sense of miserable depression in the second stage.

Alcohol usually increases the activity of the respiratory actions in a moderate degree; as did also whisky in many instances, and rum commonly, whilst brandy and gin lessened them.

Beers he believed to act also by their sugar and gluten, and thus tend to promote the digestion of starchy food; but for this purpose only small quantities, as by an ale-glass, should be taken at a time, so as to obtain this action apart from the alcoholic action.

The author also appended a few remarks on the action of coffee, on account of its parallel use with tea, and proved that whilst both agree in increasing vital action, they differ in the important particular of their action upon the skin. Coffee usually lessens the action of the skin, and thereby renders it dry and hot, at the same time increasing the action of the heart, and, as a further consequence of the former, increasing the action of the kidney, or failing that, inducing diarrhœa. Hence it is applicable in conditions widely differing from those suited to the use of tea.

In contrasting tea and coffee with alcohols, the author found only one analogy with tea, viz. that of beers, since both tend to promote the digestion of starchy food, and therefore both the teatotallers and the anti-teatotallers may be equally right. There is no similarity whatever between the action of tea and alcohols; but both are in their essential actions opposed, whilst there is an important correspondence in the action of alcohols and coffee. The use of tea in the arctic regions must be associated with that of alcohols, or the substance having an equivalent but less perceptible and more enduring action upon the skin, viz. fats, whilst rum is less injurious to the sailor of all countries than brandy or gin would be, by its special power of increasing the respiratory and other vital actions. When it is conjoined with milk, it is the most perfect restorative known.

The author did not regard any of these substances as true food, viz. substances which by their own elements directly nourish the system, but having the special power of curtailing the power of assimilating other food. Hence, although there may not be "more nutritive matter in a pint of beer than will lie upon a sixpence," there is a power whereby other food is made more useful to the system.

The Physiological Relations of the Colouring Matter of the Bile.

By J. L. W. Thudichum, *M.D.*

The author having convinced himself by experiment that the ordinary method of purifying cholochrome (the colouring matter of bile) does not give a uniform material, has sought for such a reaction as would give the rational composition of this substance in order to establish its formula by metamorphoses. Such a reaction he has obtained with nitrous acid, which, when passed in the gaseous state into water, alcohol, or ether containing cholochrome in suspension in a finely divided state, decomposes the latter with effervescence due to the evolution of nitrogen. There remains in the vessel a new acid, viz. cholochromic acid, insoluble in water, but soluble in alcohol, ether, and chloroform, and very changeable on exposure to air. It crystallizes in dark-red rhombic octohedra when its solution in chloroform is evaporated in a current of hydrogen or coal-gas, and the crystals much resemble those of hæmatoidine. The hæmatoidine extracted by Valentiner and Brücke from gall-stones and ox-bile has some resemblance to this new acid. From the above reaction it is evident that cholochrome, like the other acids of the bile and like hippuric acid, leucine and tyrosine, and many other substances connected with the human economy in health and disease, is an *amido-acid*, i. e. an acid in which the nitrogen is contained in the form of amide (NH^2); this radical replacing one equivalent of hydrogen in the hypothetical acid, of which the cholochromic is the oxyacid, the radical ($N\,H^2$) in the amido-acid being replaced by peroxide of hydrogen (HO^2) in the oxyacid.

With nitric acid, cholochrome yields an amorphous yellow substance, little soluble in water, nitro-cholochrome, a crystallizable acid easily soluble in alcohol, perhaps nitrocholic acid; and a colourless syrupy acid easily soluble in water, and yielding a crystallized salt with ammonia, perhaps cholesteric acid or a homologue. Chlorine transforms the brown matter, cholophaine, into the green cholochloine in the space of a few minutes. The process of Heintz required several weeks for effecting the same transformation. The continued influence of chlorine produces the red cholochromic acid, which exists, however, only for a moment, being transformed into white chlorocholic acid, little soluble in water, more soluble in alcohol.

These researches have been undertaken by Dr. Thudichum, partly with a view of ascertaining the pathological process which gives rise to certain casts of the biliary ducts, previously described by him in the 'British Medical Journal.' He believes it to resemble the putrefaction of bile in a stoppered bottle. If the process is acute, it constitutes "biliosity or biliousness;" if more chronic, it gives rise to casts of the ducts and gall-stones; if it extend to the liver-cells, it constitutes malignant jaundice.

The author further intimates that, since the above reaction with nitrous acid is now ascertained, the therapeutic effects of nitric and nitro-hydrochloric acids in various forms of jaundice, which are already recognized by many practitioners, are deserving of further investigation and trial. His own experience is in favour of these remedies.

GEOGRAPHY AND ETHNOLOGY.

Opening Address by the President, Sir RODERICK IMPEY MURCHISON, *D.C.L., F.R.S., V.P.R.G.S. & V.P.R.G.S., Director-General of the Geological Survey of the United Kingdom.*

DURING the last two years only, the President of each Section of the British Association having usually opened the business of the Meeting by a short address, it fell to my lot to offer a few words to the Geographers and Ethnologists who were assembled at Leeds in 1858. I there expressed the satisfaction I felt in proposing, at the Edinburgh Meeting in 1850, the formation of a separate Section for Geography and Ethnology, to occupy the place left vacant by our Medical Associates who had seceded to found an Association of their own.

Until that year Geography had been attached exclusively to the Geological Section, in which it was almost submerged by the numerous memoirs of my brethren of the rocks, whilst Ethnology, forming a Sub-Section, with difficulty obtained a proper place of meeting. Now, however, both these sciences are, I am happy to say, fully represented, and I trust that the result of the coming week will show that the subjects to be illustrated will attract so many members to our hall, as will prove that Geography in its comprehensive sense is as popular in Oxford as it is in the metropolis.

Before I enter upon the consideration of any memoirs which may be laid before us, let me allude to a few of the subjects of deep interest which have been illustrated by British Geographers in various parts of the world in the two years which have elapsed since I had the honour of last presiding over you.

In Africa, the earlier discoveries of that great traveller Livingstone have been followed by other researches of his companions and himself, which, as far as they go, have completely realized his anticipation of detecting large elevated tracts, truly *Sanatoria* as compared with those swampy and low regions near the coast, which have impressed too generally on the minds of our countrymen the impossibility of sustaining a life of exertion in any intertropical region of Africa. The opening out of the Shire river, that grand affluent of the Zambesi, with the description of its banks and contiguous lofty terraces and mountains, and the discovery of the healthfulness of the tract, is most refreshing knowledge, the more so as it is accompanied by the pleasing notice, that the slave trade is there unknown except by the rare passage of a gang from other parts. Again, this portion of the country so teems with rich vegetable products, including cotton, and herds of elephants, as to lead us to hope that the spirit of profitable barter, which powerfully animates the natives, may lead to their civilization, and thus prove the best means of eradicating the commerce in human beings.

Whilst Livingstone was sailing to make his last venture, and to realize the promise he had given to his faithful Macololo friends, that he would return to them, and bring them kind words from the Queen of the people who love the black man, Captains Burton and Speke were returning from their glorious exploits in a more central and northern region of South Africa, where they had discovered two great internal lakes or freshwater seas, each of not less than 300 miles in length.

I may here notice, to the honour of our Government, and particularly to that of the present Secretary of Foreign Affairs, that the undaunted Captain Speke, associated with another officer of the Bengal army, Captain Grant, has received £2500 to enable him to terminate his examination of the great Nyanza Lake, under the equator, and we have reason to hope that he will find one of the chief feeders of the White Nile flowing out from its northern extremity, and thus determine the long-sought problem of the chief source of that classic stream.

I also trust, that in the last and most arduous portion of his efforts in proceeding northwards, he will be assisted through the cooperation of Her Majesty's Consul at Khartum on the Upper Nile in traversing the country immediately to the north of the equator, where no traveller, ancient or modern, has ever penetrated, and which is inhabited by wild and barbarous natives. After a residence of sixteen years in that region, and having made many trading expeditions to the confines of this unknown region, that bold and experienced man, Consul Petherick, is, I am persuaded, the only European who can afford real assistance to Captains Speke and Grant; and if by their united efforts the true source or sources of the Nile should be discovered, Britain will have attained a distinction hitherto sought in vain from the days of the Roman Empire.

During the week of our meeting, Mr. Petherick will bring before us his project, which I trust you will support *, either for ascending the Nile to its source or affording effective assistance to Captain Speke, without which it is much to be feared that the gallant officer will never be able to traverse the savage tracts which intervene between the Nyanza Lake and the highest part of the Nile yet visited by any traveller.

If we turn to the Polar Circle, we see what individual British energy has been able to elicit from the frozen North. There, indeed, notwithstanding many a well-found expedition sent out to ascertain the fate of Franklin, all our efforts as a nation had failed, when the energy and perseverance of a woman, backed only by a few zealous and abiding friends, accomplished the glorious end of satisfying herself, and of proving to her admiring country, that in sacrificing their lives, her heroic husband and his brave companions had been the first discoverers of the North West Passage.

For her noble and devoted conduct in having persisted through so many years to send out expeditions at her own cost, until she at length unravelled the fate of the 'Erebus' and 'Terror,' the Royal Geographical Society of London has rightly judged in awarding to Lady Franklin one of its Gold medals, whilst the other has been appropriately given to that gallant and skilful officer Sir Leopold M'Clintock, who in the little yacht the 'Fox' so thoroughly accomplished his arduous mission. He not only ascertained the death of Franklin, and the subsequent abandonment of his ships, but also showed that the great navigator had discovered vast breadths of Arctic lands and seas which were entirely unknown when he left our shores, and had even remained so until the truth was revealed by the expedition of the 'Fox.'

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* A Subscription List in furtherance of this great object is opened, headed by Lord Ashburton and Sir Roderick Murchison.

The geographer who compares the map of the Arctic regions as laid down by Parry and others up to the year 1845, when Franklin sailed, and marks on it all that he is now known to have added in the two brief summers before he was beset, and then inspects any one of the most recent maps, even up to the year 1858 inclusive, and traces the discoveries made by M'Clintock and his associates, Hobson, Young, and Walker, will see what vast additions to geographical knowledge have been made by the last expedition of Lady Franklin.

Such services are indeed worthy of the highest national reward, and I have, I am happy to say, reason to know, that a monument in commemoration of the glorious deeds of Franklin and of his having been the first to discover a North West Passage will be erected, and also that the officers and crew of the 'Fox' will receive that recompense to which they are so justly entitled at the hands of their admiring countrymen.

Whilst on this subject, I may well express the satisfaction and pride I felt as the President of this Section, when the officers of the British Association asked us, the Geographers, to bring forward one of our distinguished men to deliver a lecture on one of our manifold subjects, before the body of men of Science assembled at Oxford. As this is the first occasion since our foundation on which geographical discovery has been considered to be of sufficient scientific importance to occupy the attention of the whole meeting, I rejoice in the fact, and also in the knowledge that Captain Sherard Osborn, so well known to us through his charming 'Arctic Stray Leaves,' and other books, as well as by his laurels won in the Crimea and the Sea of Azof, is to be the lecturer, and that he who is so experienced an ice-man is to give us a sketch of the discoveries of Franklin, as laid open by the last researches of Sir Leopold M'Clintock.

And here I may well say, that every justice will be done to any subject connected with the conditions of icy seas, including the proposed submarine telegraph by the Faroe Islands, Iceland and Greenland to Labrador; for never at any of our former meetings have I seen so many explorers met together who have rendered their names eminent through Arctic and Antarctic discoveries. Under their observation the paper which is to be brought before us by Captain Parker Snow of the Merchant Marine, warmly urging a further search after the missing crews and scientific records of the 'Erebus' and 'Terror', will be ably scrutinized. The names of Admiral Sir James Ross, Sir Edward Belcher, Captains Ommaney and Sherard Osborn, when united with those of Sir J. Richardson and Dr. Rae, are truly guarantees that the question will have so much light thrown upon it, as will either satisfy the public that no additional important results as respects the lost expedition can be achieved, or they will stimulate us to fresh exertions. For, though all the Arctic voyagers with whom I have conversed are satisfied that there is now no longer the hope, which I long cherished, of saving a human life, still every man of science must wish that strenuous efforts should be made to recover, if practicable, some more of the many scientific records of the lost expedition which may have been left in various places around the spot where Franklin breathed his last.

In the vast possessions of British North America much additional knowledge has been gained by the successful explorations of Palliser and his associates, Hector, Blakiston, and Sullivan, not only as respects the great fertile prairies watered by the Saskatchewan and its affluents, but also touching the practicability of traversing the Rocky Mountains within our territories by passes lower than any which exist to the south of the boundary of the United States.

At this stage of our inquiries it would be very hazardous to speculate on these passes being rendered available for railroads; the more so, as the wild region lying to the west of the Rocky Mountains—*i. e.* between them and those parts of British Columbia which are gold-bearing, and are beginning to be inhabited by civilized people—is as yet an unexplored woody region. We may hope, however, that such routes of communication will be established as will connect the Red River settlements with the prairies of the Saskatchewan, and these last with the rich auriferous tracts of British Columbia. And if the most northern lines be found too difficult for railway communication, through the severity of the climate and physical obstacles, let us hope that by giving and taking ground in an amicable manner with our kinsmen of the United States, we may be enabled by a more southern railroad to traverse the prairies on either side of the neutral boundary, and then pass down the river Columbia to Vancouver Island. By this operation the great Gulf of St. Lawrence and Hudson's Bay on the east, may eventually be placed in communication with the noble roadsteads of Vancouver Island and the adjacent mainland on the Pacific. At all events, Britain will doubtless not be slow in establishing communications between the Atlantic and Pacific, first by the electric telegraph, next by ordinary roads, and finally, it is to be hoped, in part at least, by railroads.

On these subjects we are to be favoured at this Meeting with a paper by Captain Synge, in addition to the *vivâ voce* communications of Captain Palliser and his associates.

Having not as yet had access to many of the papers which are to be communicated to this Section, I can allude to a few more of them only. In a Memoir on the Geographical Distribution of Plants in Asia Minor and Armenia by my distinguished friend M. Pierre de Tchihatcheff, you will find some remarkable results as flowing from the long-continued researches of that ardent and successful traveller. After accounting for the absence of some plants and the profusion of others in given localities as dependent on climatal conditions (an example of which is, that the grape there flourishes in one tract at the great height of nearly 6000 feet above the sea), M. de Tchihatcheff brings out some striking statistical data, showing the vastly greater abundance and variety of vegetation in Asia Minor compared with that of any other country. He points out that the plants of five mountains only amount in number to double the entire quantity of British plants, and concludes with an eloquent regret that these classic regions, so blessed by the hand of the Creator, and which in the earlier history of mankind were replete with highly civilized communities, should now, through misgovernment, be the scene of oppression and barbarity.

Another distinguished Russian geographer, M. N. Khanikoff, who has explored large portions of Persia and the adjoining countries, will bring before us his maps and descriptions of the mountainous tracts of the countries of the southern parts of Central Asia, where the lofty mountains of Ararat, Demavend, and Savalan form the chief elevations of the region to which we look as the cradle of our race.

But, to revert to subjects connected with Britain. In no portion of the surface of the globe have we made such great and rapid advances as in Australia. Doubtless much of this progress in settlement and civilization, particularly in Victoria, is due to the discovery of those enormous masses of gold which are producing far and wide such powerful effects. But looking to the work of purely geographical pioneers, I can declare, that some of the most valuable and daring researches from the earliest days to the present time have been completed, wholly irrespective of profits gained through the attraction of the precious metal. The great discoveries of Sturt, Eyre, and Leichhardt were made before the existence of gold was known; and even now, when it is the most seductive of baits to entice the traveller, see what vast regions the brothers Gregory have laid open in Northern, Eastern, and Western Australia without the recompense of a single yellow nugget. Again, look to South Australia, where gold is scarcely known, at least in any appreciable quantity, and see what its inhabitants have done in pushing far into the interior, simply to acquire fresh pasture-lands. In contemplating these recent discoveries, we read with astonishment of what one individual, Mr. M'Dougall Stewart, has accomplished in so short a time, and of the privations he underwent to realize the existence of freshwater streams and oases on the borders of the great interior saline desert.

Still more were we surprised when we learned that this great continent, the rivers of which were so long considered to be useless, has had its one mighty stream, the Murray, rendered navigable for 1800 miles. With its affluents, the Darling and Murrimbidgee, this river may indeed be said to have been laid open for 2500 miles, *i. e.* between many new towns which have sprung up in the interior and the sea—and all this by the clearing away of the stems and stumps of trees, the result of ages of decay.

There are now indeed in England some of the eminent men, whether governors, statesmen, or explorers of this great colonial region, who will, I hope, before we adjourn, throw fresh light on these recent discoveries.

Having presided for several years over the Royal Geographical Society, it has been my duty to pass in review the progress made by the sons of Britain in different parts of the world, and it has ever been to me a source of the sincerest gratification to watch the rapid strides made by the colonists of Australia, and to observe how they have carried with them all the energy of our race into the land of their adoption. If I traced with deep interest the explorations of their boldest travellers through the bush—and witnessed with delight the working out of that golden wealth, of which perhaps, because I was a Highlander as well as a geologist, I had a sort of *second sight*—or if I revelled in seeing their ports filled with ships, and abounding in commerce—not all these attributes have rejoiced me more than the knowledge I acquired, that our Australian colonists are truly and sincerely attached to Britain and their Sovereign.

As it is out of my power on the present occasion to advert to all the recent advances in ethnology, I will now only say, that, besides many communications from other gentlemen, including Mr. Lockhart's excellent notes on China, my eminent and valued friend, Mr. John Craufurd, will give us two memoirs; the one, "On the Relation of the Domesticated Animals to Civilization;" the other, "On the Aryan, or Indo-Germanic Theory;" each of which will, I doubt not, be worthy of the President of the Ethnological Society of London.

Let me, however, offer a few general observations on those sciences, to the cultivation of which the business of this Section is devoted. Geography, regarded only as the description of the outlines of the earth, and the determination by astronomical observations of the relative position of hills, rivers, valleys, and coasts, to be laid down by the topographer on a map, is but the key-stone of that splendid science when viewed in its most comprehensive bearings. For, of how much real value is it deprived if not followed in its train by all the affiliated sciences which relate to the phenomena of our mother earth! How infinitely is the important basis of our science enriched by the descriptions of the animals and plants which, living on the surface of our planet, are distinguished by forms peculiar to each region—such distribution being coincident with relative differences of climate!

Again, as a weather-beaten geologist, I know full well, that the science which I have most cultivated would be void of a foundation if it did not rest on the principles of physical geography; for much of the labour of the geologist consists in restoring, not in imagination, but by a positive appeal to data registered on tablets of stone, the former outlines of sea and earth at different successive periods, whilst he marks the various oscillations of land and water as well as the necessary accompaniments of grand meteorological changes.

If therefore the geographer is guided to the relative position of his localities by the lights of astronomy, he also knows that accurate observation of all terrestrial changes is of the highest value in enabling his ally the geologist to interpret and read off the former conditions of the crust of the earth. Just as geography in its present phase is necessarily connected with ethnology, so its earliest features as a science can best be thoroughly comprehended by the geologist. His is the province to bring to the mind's eye various relations of land and water through the olden periods, when most of our present continents were formed beneath the sea; and to trace the successive elevations and depressions which characterized epochs long anterior to the existence of man. Even in those remote times when some lands were elevated and others depressed, we have ascertained that the waters and the earth were occupied by various animals which successively lived and died to be followed by other and more highly organized races, until at length a being endowed with reason was created.

And when, having gone through all the long epochs of geological time, we approach the period when man appeared, how interesting is it to endeavour to unravel the changes which our lands underwent from that recent geological date when the British Isles formed part of the *terra firma* of Europe! Then at a later period, how inviting is it to mark the signs of the commixture of the rudest and earliest works of man with the remains of animals, most of which are now extinct, yet mixed up with others which have lived on to our own day!

Thus, whilst the geological geographer visits the banks of the Somme, and sees such an assemblage of relics beneath great accumulations formed by water (as I have recently witnessed myself), he is compelled to infer, that at the period when such a phenomenon was brought about, the waters which have now diminished to an ordinary small river, rose in great inundations to the height of 100 feet and more above the present stream, and swept over the slopes of the chalk on which the primeval inhabitants were fashioning their rude flint instruments—when, as I would suggest, they might have escaped to the adjacent hills, and saving themselves from the sweeping flood, have left no traces of their bones in the silt, sand, or gravel.

This linking on of geology with human history and the works of primeval art comes legitimately under our consideration, and here we have just as full right to discuss and test this question as my dear friends the geologists, the more so as it was to this connexion between geology and history that Lord Wrottesley has called the attention of the Association in his Presidential Address.

Then, again, as we descend with the stream of time until we reach historical records, the geographer next endeavours to throw light on the marches of the great generals of antiquity and the sites of ancient cities; and then truly the geologist, geographer, and ethnologist become united with the antiquary and historian. Taking our recent British example of the discovery of the Uriconium of the Romans at Wroxeter in Shropshire—where is the geographer who has looked at the mounds of earth which till recently covered that ancient city, and is not convinced, that causes arising from the combined destruction by man and natural decay, have produced the mass of overlying matter on the shores of the Severn, which has hidden from our vision one of the famous Roman towns of Britain?

As I have delighted in tracing the sites of the battles of our great British chief Caractacus*, and in unravelling the age of those Silurian rocks in which he made the chief defences of his own kingdom, so I can now bring back to my imagination how the legions of Ostorius may have been reinforced from that Uriconium, which has just been disinterred from its earthy covering by the zealous labours of the enlightened antiquary Wright, now a Secretary of this Section.

In this manner we see, that as our inquiries necessarily stimulate us on the one hand to recede to the very earliest traces of man upon the globe, so, on the other, we are led on into that department of Art and Archæology which connects the present with the past, and are thus enabled to offer to the consideration of our associates and auditors, subjects of prevailing and universal interest—subjects which will, I doubt not, be handled with redoubled zest, now that we are again happily met together for the third time in this very ancient seat of learning.

In conclusion, Ladies and Gentlemen, I have now only to congratulate you on the recent rapid extension of geographical science throughout the enlightened classes of our countrymen. Brought up with a profound reverence for the works of God, and a due admiration of the finest efforts of man, those sons of our gracious Sovereign who are of sufficient age to profit by extensive travel, are already proving, that in their spirit of adventure they are true Englishmen. The heir to the crown, after rambles in our Scottish Highlands and travels on the continent, is about to quit this his Alma Mater, and, to the great joy of our colonists, to visit North America, and there rivet still more strongly the link which binds the loyal people of those provinces to the mother country; whilst Prince Alfred, after cruizing in the Mediterranean, is now sailing across the Southern Atlantic to Bahia, not without having ascended on his way to the very summit of the Peak of Teneriffe. The willing cooperation of the last and present President† of the Royal Geographical Society demonstrates that our nobility are as much alive to the vast importance of our subject as the middle classes of the community. On my own part, having laboured zealously in diffusing geographical knowledge among my countrymen, I can truly say that my gratification is now complete in seeing that this Section is second in popularity and utility to no branch of the British Association.

On the Caravan Routes from the Russian Frontier to Khiva, Bokhara, Kokhan, and Garkand, with suggestions for opening up a Trade between Central Asia and India. By T. W. Atkinson.

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* See the Preface to the 'Silurian System.'

† Earl de Grey and Ripon, and Lord Ashburton.

On the Caravan Route from Yarkand to Mai-matchin, with a short account of this Town, through which the Trade is carried on between Russia and China. By T. W. ATKINSON.

On the Manufacture of Stone Hatchets and other Implements by the Esquimaux, illustrated by Native Tools, Arrow-heads, &c. By Captain Sir E. BELCHER, *R.N.*

Sir Edward commenced by setting forth his belief in the connexion of the northern littoral tribes of Asia, America, and Greenland in habits, customs, and language, differing less in this latter point than in our counties in England, Wales, or Scotland. Comparing the American with the Asiatics, the Tchutchi, he found the latter more experienced or accomplished in music, manufacturing their own violins, and performing wonderfully, imitating *à la Paginini* on one string the sounds of various animals; they were also good buffoons and actors as imitating the anctics of bears, &c. But as regards the useful arts, or those calling for invention or energy in overcoming difficulties, improving tools, weapons, &c., they were much inferior to the Esquimaux of America, and certainly far below them in mental acquisitions. Sir Edward then gave an interesting description of the habits and manners of the tribes with which he lived in contact near Icy Cape. He obtained great influence over them, and so long as he continued to teach them any new mode of working they submitted to his direction. He had no doubt, if necessity had compelled him to remain there (as he was wrecked there), he might have existed and possibly become one of their chiefs. This disposition on their part to associate with and be instructed by white men, confirmed him in the notion he had entertained, that possibly one or two of the crews of the 'Erebus' and 'Terror' might have escaped and be now willingly living among them.

The principal object of the paper was to explain the stone implements found among them, and similar to those of Celtic origin, as well as their mode of manufacturing them from a vein of chert at hand. Sir Edward saw them obtain the chert from the stratum, work them into spear and arrow-heads, and there purchased the articles as well as the tools employed which were explained in detail to the Meeting. No hammer or blow is used in splintering off the conchoidal splinters to form the serrated edges, but a tool of deer antler effects this by pressure on the faces alternately. Sir Edward also observed that the same process is adopted by the Indians of Mexican origin in California, by the natives of the Sandwich Islands, as well as Tahiti, 2300 miles asunder. Other curiously wrought and interesting instruments, as planes, drill bows, &c., were exhibited, all manifesting great skill and a higher degree of mechanical ability than we could expect from an untutored race—indeed a race taking the lead pre-eminently in meeting scientifically those wants occurring in savage life. With reference to their ornamentation of their drill bows, &c., Sir Edward maintained that they exhibited proofs of record, which Dr. Rae considered to be wanting in the tribes encountered by him some degrees to the eastward. Steam, and the mode of using it, to bend or straighten bows or arrows, was constantly employed by them; and Sir Edward concluded by expressing his conviction that these people were in a condition to be rendered useful by civilization, and thus open more lucrative trade with the western and southern nations in the Pacific.

On the Aryan or Indo-Germanic Theory of Races.
By JOHN CRAWFURD, *F.R.S.*

The object of the writer of this paper is a refutation of the Aryan or Indo-Germanic theory, or that which supposes all the peoples from the eastern confines of Bengal to the western shores of Spain and Britain to be of one and the same race of man, on the evidence of a fancied identity of language. A few of the main objections advanced by the author may be stated. The theory supposes a people, whose language was the Sanskrit, to have migrated at some unknown time, spreading east in one direction and west in another, and to have performed these prodigious migrations, although an agricultural people, or in other words, one of fixed habits. The theory makes men who are black like the Hindus, brown like the Russians, and fair like the Scandinavians, to be of one and the same race, insisting that the Greeks of Alexander and the Englishmen of Clive had the same blood in their veins as the Hindus whom a handful of them vanquished. As to the supposed identity of race from the evidence of language, the author considered it sufficiently disposed of by the notorious fact that many of the languages of Hindustan spoken by people asserted to belong to the Aryan stock, had no fundamental relation to the Sanskrit tongue of the supposed Aryans. In Europe, the isolated Basque language was evidence to the same effect.

On the Influence of Domestic Animals on the Progress of Civilization (Birds).

By JOHN CRAWFURD, *F.R.S.*

The object of this paper, one of a series on the same subject, was to show the effect of the domesticated animals in the civilization of man, and was confined to birds. The author showed that out of the vast variety of the feathered creation, not above nine or ten species had been domesticated, while there was a wide range in the quality and amount of the domestication which even this small number had attained. The origin of a few of the species only could be traced to particular countries, as the common fowls to India and China, the turkey to Mexico, and the gallinæ to Africa. But he seemed to think that the first domesticated of the greater number was common to several countries, as the grouse, pigeon, duck, to most countries of Europe and Asia. The author further showed that the numbers of birds domesticated by a people might be considered a measure of their relative civilization. Thus savages possessed no domestic bird at all; barbarians very few, and the most advanced only the whole number. Thus the savage tribes of America possessed none at all. The Mexicans possessed but one. The more advanced tribes of the South Sea had one, the common fowl, while the Australians had none. The Malayan nations were possessed of two, the common fowl and duck; the Persians of these and the pigeon, and Hindus of the last three with the peacock; and the Chinese of five, the common fowl, the goose, the pigeon, and two species of pheasant. It is the more civilized nations of Europe alone that possess the entire number.

On certain remarkable Deviations in the Stature of Europeans.

By R. CULL.

On the Existence of a true Plural of a Personal Pronoun in a living European Language. *By* R. CULL.

On a Set of Relief Models of the Alps, &c.

By Captain CYBULZ, *Imperial Austrian Artillery.*

The author desires to introduce to the notice of this Meeting a set of models, intended to facilitate instruction in the manner of delineating the features of the ground on topographical maps, and lately introduced into the technical schools of Austria. It is the first aim of the author to lead the pupil, by means of these models, to a correct understanding or appreciation of *form*, as the only way of producing a first-rate topographical draftsman. Instead, therefore, of setting him to imitate drawings from paper, his studies and copies will be made from models, and, at a more advanced stage, from nature itself. These models represent, first, inclined planes or slopes, separate, in combination, or intersecting each other. It is from these the pupil acquires the first idea of the principle upon which depends a correct delineation of the ground. Secondly, we have three models which represent the most characteristic and most widely distributed features of the ground. Having acquired from the preceding a thorough knowledge of fundamental principles, the pupil will proceed to delineate upon paper the following models. These represent, first, an undulating country; secondly, a plateau formation, with deeply-cut valleys; thirdly and fourthly, some mountainous tracts. Contour lines have been laid down upon the whole of these models with mathematical accuracy. The horizontal projection of some of the most difficult sections has also been added, to illustrate the manner of filling up the contour lines and laying down auxiliary contours. It has not, however, been thought advisable to do more, as otherwise the pupils would avail themselves of these facilities to too great an extent. A small instrument for measuring the gradients, and a scale showing the intensity of the shading (*hachorres*) for various degrees of acclivity, are to be made use of in copying the models. The author believes that the use of models, judiciously selected, will engage the pupil's uninterrupted attention; he will overcome mechanical difficulties with greater facility, and will not be so wearied as by the tedious, but abortive, and, in reality, useless attempts to copy a topographical drawing placed before him. The author would add, that his models have been made of galvanoplastic copper, and are therefore not so liable to breakage as plaster-of-Paris models.

On the Arrangement of the Forts and Dwelling-places of the Ancient Irish.

By the Rev. Professor GRAVES, *M.A.*

On certain Ethnological Boulders and their probable Origin.

By the Rev. EDW. HINCKS, *D.D.*

The author began by observing that, if a geologist were to see a mass of stone lying in a place where all the rocks around were of a totally different character, he would not be satisfied till he had accounted for its being there; till he had found whence it came, and at what period, and by what agency it was brought. He believed that like inquiries should be made, and might be answered, respecting ethnological boulders; by which he understood words occurring in writings of remote antiquity, which were of a totally different character from the words of which the writings were mainly composed. He believed that it would be possible, by help of these boulders, to trace the people to whose language the words belonged, along the line by which they must have travelled, forward to the point where their migration terminated, and backward to that where it must have commenced. In the present paper he proposed to do this in a particular case, the discussion of which was peculiarly appropriate to the present meeting, as it related to that language, a proficiency in which was the acknowledged glory of Oxford.

The language of the Assyrian inscriptions is of the family called Semitic, that is, of the same family with Hebrew; and by the way it resembles this language in some important particulars, such as having a Niphhal conjugation, more closely than it does any other known language of that family. It is remarkable also that the copious inscriptions which exist in this language were all written between the writing of the earliest and the writing of the latest books of the Old Testament; so that it would seem that no language could be expected to clear up what is obscure in these books so well as the Assyrian.

In these Semitic inscriptions, however, numerous words are to be met with which are evidently not Semitic. One class of such words was pointed out several years ago by Sir Henry Rawlinson. They belonged to the language of Chaldea or Accad, which was spoken to the south of Assyria, and which he pronounced to be an Hamitic language, akin to the Egyptian.

In a paper read at the Dublin Meeting of the British Association in 1857, of which a copious abstract is given, pp. 134–143 of the Report, Dr. Hincks took a very different view of the matter. He maintained that this Accadian language represented a sister language to that which is the common parent of all the Indo-European languages; the common parent of these two, which he called the Japhetic language, being a sister to the Egyptian language and to the common parent of all the Semitic languages. He now affirmed that the views contained in that paper (with which he must, for brevity, assume that his hearers were acquainted) were fully confirmed by his subsequent researches, and that he had met with nothing inconsistent with them. The linguistic pedigree there laid down was so fully established by induction from a number of verbal pedigrees that it needed no further confirmation. Still, comparisons of Indo-European words with words of one of the languages above named, which was not Indo-European, would be found useful, and that in three ways:—

1. Such a comparison might establish the fact of a word having been in use in the

original family from which the Indo-European races have sprung. This fact may be inferred from the word being used by remote subfamilies; but its being used by two subfamilies (or even by a single one), and being also found in one of the languages that are cognate to the original Indo-European, but not derived from it, is still stronger evidence. Thus the word *horse*, which is peculiar to the Teutonic family, but which is cognate to the Latin *curro*, "I go like a horse, *i. e.* I run," is shown to have been in use in the original Indo-European family from its evident connexion with the Accadian *kurra*. The original Indo-European root must have been *kurs*.

2. Such a comparison may determine the original form of an Indo-European root, which varies in the different languages known to us; as it may also determine the original Semitic form. For example, in p. 141, Report for 1857, the facts that the original Indo-European form of the second numeral was *thwi* and the original Semitic form *thni*, could only be established by a comparison of the different forms known to exist with the Accadian *mi*, as explained in that paper. In treating of the words for "lion," No. 14, he was ignorant that the Assyrian word was *libbu*. Comparing this with the Accadian *lig*, he now thinks that the Semitic form must have been *ligb*, and that this was also the Japhetic form. The Indo-European root would be *ligw*. In Latin this would be declined *lix*, *livis*; and, as (*s*)*nix*, (*s*)*nivis* gives *snow* in English, and *snig*, *sneg* in the Letto-Sclavonian languages, so *löwe* in modern and *lew* in older German correspond to *lix*; and *lig* might be the ancient Letto-Sclavonian root, equivalent to these.

3. An etymological relation between Indo-European words may possibly be established if both can be shown to correspond to the same word in a language which is not Indo-European. Thus, the relation between *γλυκὺς* and *γλῶσσα* is not generally admitted by Greek lexicographers; though if the words be written as they would be in the Cadmean alphabet (see p. 142 of the former paper), *γλοκ-Ϝες* and *γλοκ-ια*, the resemblance is easily seen. But this relationship is established when we find that *ghlu* is used in Egyptian both for "sweet" and for "tongue." The Latin *dulcis*, originally *dlucvis*, is cognate to these.

Enough, however, on the subject of the Accadian words occurring in the Assyrian inscriptions. They present no ethnological difficulty, as the people who spoke the language to which they belonged lived close to Assyria. The case is the same with the Semitic words which occur in the Egyptian inscriptions. He pointed out one in 1845; מרכבת "a chariot;" used also for "chariots;" the Egyptians not generally expressing the vowels, and thus writing the terminations *eth* and *ôth* alike. Mr. Birch has since found another meaning, "round bucklers," which appears to be the Arabic مقر صدين. These are Canaanitish words, expressing objects brought from Canaan.

There were words, however, in the Assyrian inscriptions which Dr. Hincks believed to be Indo-European; and as no Indo-European people had been hitherto recognized as existing on the west of Assyria, their existence presents an ethnological difficulty which the author seeks to explain in this paper.

The words in question were *ligwindinas* and *lâsanan*. The former occurs on a great slab or altar in the north-west palace at Nimrûd (B. M. Series, pl. 44, l. 17). Every other word in the sentence is of known signification. "*L.* alive I took captive." From the context it must necessarily be the name of an animal, in the plural number (being joined to a plural adjective) and in the accusative case (being governed by a transitive verb). Every one who has the slightest knowledge of the grammar of the Semitic languages must see that *ligwindinas* cannot be a Semitic accusative plural; and every one that knows anything of the grammar of the Indo-European languages must see that it is a regularly formed Indo-European accusative plural. Taking it as Sanskrit or Zend, the nominative singular would be *ligwindi*; taking it as Greek, it would be *ligwindis* or *ligwindin*. Whatever be the particular language to which it belongs, and whatever be the meaning, its being Indo-European ought not to be questioned. The other word, *lâsanan*, has puzzled the interpreters of the Assyrian inscriptions as much as any other word. It occurs in several contexts: "king *lâsanan*" after "king of Assyria" on Bellino's cylinder, l. 1; "ruler of the tribes *lâsanan*," on the Tiglath Pileser cylinder (I. 29), "wielder of the sceptre *lâsanan*," same cylinder (VI. 56). "Assur the great lord has made me to *possess* (? *yusadlimanni*; the first radical may be ד, ט or ח) the kingdom *lâsanan*," Bellino's cylinder,

l. 4. In all these contexts, a genitive of the name of a people who were not Assyrian seems required. Yet *lâsanan* is an impossible form for a Semitic genitive. The word לשׁן, "a language, *i. e.* a people speaking a language," suggests itself at once; but its genitive plural would be *lisanâti*. The idea that *lâsanan* should be resolved into two words, the first being *lâ*, the negative particle, suggested itself also; but to this also there were insuperable objections. *Sanan* is, no doubt, the theme of an adjective; but when joined to a noun it must have a case ending. In the first context the rules of grammar would require *sannu*, in the second *sannâti*, in the third *sanatti* euph. for *sananti*. In the fourth *sarrut* is in construction, and would require a genitive after it, and not an adjective. The same might be said of *kissat* in the second context. Besides, *lâ sanan* would mean "not fighting," and would be the very last title that a king of Assyria would apply to himself. The translation "unchanging," which has been suggested, would require *lâ sanah*, in place of *lâ sanan*, if the case ending were to be omitted, which, however, it could not be. Whether, therefore, *lâsanan* be regarded as one Assyrian word or as two, it presents insuperable difficulties. These, however, disappear at once if it be considered as an Indo-European word. It has all the appearance of an Indo-European genitive plural from a nominative *lâsas*; and such a word is just what will suit all the contexts. Accordingly, the recognition of *ligwindinas* as Indo-European led immediately to the recognition of *lâsanan* as so too.

The next question to be considered is to what country the Indo-European people who used these words belonged.

The account of the hunting expedition in which the Assyrian king took the *ligwindinas* is preceded by that of his receiving tribute from the people on the coast of Syria, beginning with the Tyrians and ending with the Arvadites. This renders it probable that his hunting was on the west of Assyria; and indeed he states in the Pavement Inscriptions that he hunted on the banks of the Euphrates. Again, if the word *lâsanan* signified a people, other than the Assyrians, over whom Tiglath Pileser acquired dominion, they must have been to the west or north of Assyria; for he mentions no conquests towards the south; and we know from the inscription of Sennacherib at Bavian that he was defeated by his southern neighbours, his capital taken, and his gods carried off by them. He could have had no dominion over the Medians, or any neighbouring people that have been hitherto supposed to be Indo-European.

This leads to the inquiry whether the Egyptian or Assyrian inscriptions afford any grounds for the supposition that an Indo-European population was located in Syria. Fifteen years ago Dr. Hincks pronounced certain names published by Champollion as those of the chiefs of the Khita, to be Indo-European. Four names terminating with *siro*, as Champollion read the characters, were published by him, the former part of the first name, which was that of the chief of the nation, being *Khita*, the name of the nation. Dr. Hincks affirmed in 1845 that this name must be Indo-European, and must mean "lord of Khita." He read the latter part of the name *swar*, connecting it with *κύριος*. M. de Rougé adopted this interpretation of the name, but said that the second element in it was the Semitic *sar*; to which it was replied that no Semitic compound could be formed as M. de Rougé supposed. "Lord of Khita" would be *Sar-Khitti*, not *Khita-sar*, according to the mode of arrangement of the elements of a compound name adopted by all Semitic people.

From the fact of these names being Indo-European, Dr. Hincks at first inferred that the enemies of Rameses II. were Scythians, as Champollion had supposed; but it was subsequently proved that they lived within a short distance of Egypt; and their capital *Kadish*, formerly read *Atish*, was identified with a place on the Orontes, south of Emessa. They were, in short, the *Khattaya* of the Assyrian inscriptions, and the Hittites of the Old Testament; and their religion, as shown by the Egyptian inscriptions, was clearly Canaanitish. How then could they have Indo-European names?

Conceiving it to be certain that *some* of their *chiefs* had such names in the time of Rameses II., Dr. Hincks reconciled this fact with the other by supposing that Indo-Europeans had previously overrun their country, and acquired dominion over it; but that they had adopted the religion and probably the language of the conquered people; at any rate they had failed to impose upon them their own language. The *Khita* had chiefs with Indo-European names, and doubtless of Indo-European race;

just as the English in the twelfth century had Norman chiefs with Norman names; but the great body of the people had in both instances remained unchanged.

There was thus evidence that a body of Indo-Europeans had conquered the country north of Mount Lebanon before the reign of Rameses II.; and on the other hand, there was evidence that at the marriage of Amenholp III. the Egyptian empire extended to Naharina or Mesopotamia. During this interval a peculiar form of sun-worship was introduced into Egypt, and obtained a temporary superiority. That this worship was of Aryan origin and that its introduction synchronized with the loss of the foreign conquests of the Egyptians, are generally admitted by Egyptologists. The middle of the reign of Amenholp III. must therefore have been about the time when the Indo-European invasion in question took place; *i. e.* according to Lepsius, 1506 B.C.; according to Bunsen, 1468; according to Dr. Hincks, about 1390.

Of the four proper names of Hittite chiefs which, according to Champollion, ended in *siro*, three are supposed by Dr. Hincks to signify lords of different people; the fourth (*Sopa-siro* of Champollion) he reads *Asp-iswar*, "lord of the horse." This reading (which, as well as the worship of the sun which these Indo-Europeans practised, suggests their close connexion with Persia) is confirmed by the name of *Kustaspi*, king of Kummukh, or Commagene, who, along with Razin of Damascus and Minikhimi of Samaria, paid homage to Tiglath Pileser II. It would appear that this Indo-European immigration took deeper root in northern than it did in southern Syria. The name *Kustaspi* is evidently a compound, signifying, like that of the father of Darius, "having . . . . horses;" the meaning of the participle *wista* or *kusta* being uncertain. In Sanskrit and Zend such compounds require no suffix at the end. Assuming that *kusta* signified "chosen," *kustaspa* gen. *kustaspahyâ* would signify "having a chosen horse, or chosen horses." Here, however, a suffix is added. The name is *kustaspi*, which would have for its genitive *kustaspinas*. This marked difference is an argument for the diversity of the Indo-Europeans of Syria from the Persians, though they resembled them in their sun-worship and in using *aspa* for "horse." Another argument to the same effect is derived from the impossibility of a Persian population making an incursion into Syria. Not only is the Semitic population of Assyria interposed, but either Media or Elymais would have to be traversed, in the latter of which the language was of a totally different character from any Indo-European one; while in the former a dialect of Persian was used, in which we know that *aspa* did not signify "a horse." In the Behistun inscription, which was in this dialect, "horse" is expressed by *asma*, instead of by *aspa*, as at Persepolis. See lines 86, 87 of the first column, where *dasha* and *asma* (in pure Persian *dasti* and *aspa*) are translated in the Scythic, or rather Elymean version, published by Mr. Norris, by the well-known Accadian words *habba* and *kurra*, which are constantly used in the Assyrian inscriptions for "elephants" and "horses." The true translation of the passage is this: "I divided the army. A part I made to be carried by elephants. The other part I made to swim with the horses."

These considerations lead to the conclusion that the Indo-Europeans in Syria did not come from Persia; but that the Persians and they formed part of the same body of immigrants, which divided into two bodies in Armenia or the neighbouring country. The next thing to be considered is the evidence which may exist of such a people having been settled in northern Syria and the country to the north of it.

This evidence consists of proper names of men preserved in the Assyrian inscriptions, which appear to be Indo-European compounds; and of names of districts which end in a sibilant which disappears when the word is inflected, and which must therefore be the sign of the Indo-European nominative singular; also of names of districts in the genitive singular, which also terminates in *s*.

A series of proper names of princes which all terminate alike is found in the Tiglath Pileser cylinder; namely, *Kaliantiru*, *Kiliantiru*, and *Sadiantiru*. The fact of the latter parts of the three names being the same, is strong presumptive evidence that those names are Indo-European. To determine their respective meanings is, however, the part of philology and not of ethnology. The name *Kashkash*, which occurs in the Sallier Papyrus No. 3, as that of a country in alliance with the Khita, is manifestly the *Kaskaya* of the Assyrian inscriptions; and the *Muskaya* of these last, the משך of the Hebrew Scriptures, is the *Mushush* of the Egyptian inscriptions, or, as it should rather be written, the *Muskusk*; for in ancient times the Egyptians, like the Assyrians, had no SH. They expressed that sound in foreign words by their double letter SK. In both these instances the final sibilant, which is preserved in the Egyptian, disappears in the Assyrian gentile adjective. In the name of Carchenish (*Gargamusk* of the Assyrian and Egyptian inscriptions) the case ending is preserved in Hebrew, Assyrian, and Egyptian. In Tarshish it is preserved in Hebrew, but lost in Egyptian. This name has not been met with in the Assyrian inscriptions; but the Greek form Ταρσ-ός shows that the second sibilant in the Hebrew word is a case ending. In the Tiglath-Pileser inscription names of districts are always expressed in the genitive, the character signifying "country" which precedes them, being to be read as a noun in construction, *mat*. Some of these genitives are Assyrian, as *Kummukhi*, "(the land of) Kummukh;" but others are to all appearance Indo-European, as Ligrakhinas, Ammaus, Adaus, Skaraus. These last three have a strong resemblance to the genitives of the Persian nouns in *ush*, such as Margaush, Babilaush. The *au* was pronounced as two syllables.

The next point investigated was the interpretation of the words of this language, *ligwindinas* and *lâsanan*, and their connexion with like words in other languages. The former word was supposed to be equivalent to λεοντοειδεῖς, and the latter to λαῶν. It was observed that λέων was a secondary word for "lion," the participle of a verb, which was itself derived from the primitive word λῖς, originally λεϝς. The words first introduced were nouns, from which verbs were derived. Thus *mus*, *mouse*, expressed the idea to which the name was first assigned. It had been stated, and assigned as a reason why the Sanskrit language ought to be acknowledged as the parent of the European languages, that Sanskrit was the only language in which the verb "to steal," from which *mouse*, "the stealer," was derived, was known to exist. It is very true that the Sanskrit noun signifying "a mouse" was derived from a Sanskrit verb signifying "to steal;" but this verb was itself derived from a primary noun signifying "a mouse," which was preserved in Greek, Latin, and Teutonic, though unknown in Sanskrit. As in English we say "to *ape* a person," meaning "to do to him what an ape does," *i. e.* "to imitate him;" so we might say "to *mouse* a thing," meaning "to do to it what a mouse does," *i. e.* "to steal it." In Wilson's Sanskrit dictionary four different forms of the verb "he *mouses* it" are given; but the *root*, the primary noun *mus*, is not to be found in the language at all. So much for this argument in favour of the antiquity of Sanskrit, as compared with the European languages cognate to it! Whatever weight it has is in the opposite direction.

Using the primary for the secondary Greek word for "lion," and the uncontracted form, we should have λιοειδέας. In the Cadmean alphabet, in which ι was only used as a semivowel, this would be written λεϝοϝειδέας; and the word preserved in the Assyrian inscriptions, if expressed in the same alphabet, would be λεγϝενδενας. The other word *lâsanan*, expressed in this alphabet, would be λᾶσονον, or at least might be so rendered; for, as long *a* expressed the sound of *a* in *fall* or in *father*, the corresponding short *ă* might have the sound of *o* in *folly* (which would be expressed by *o*) as well as that of *a* in *fat*. So the Assyrian *Aranta* became Ὀρόντης in Greek. In this same Cadmean alphabet, λᾱῶν would be λᾱσόον: the σ being here "κιβδηλον," or deceptive;—written, but not pronounced; as it was so late as the time of Pindar.

The dropping of the sibilant between two vowels being admitted to have taken place in a great number of instances (if not in every instance where it was originally unaccompanied by a consonant or semivowel) by all Greek grammarians; and the ων of the genitive plural being also admitted by Bopp and others to have been originally ονον and then οον (as μείζω was originally μείζονα and then μείζοα), there is no difficulty whatever in deriving the second Greek word in classical use from that preserved in the Assyrian inscriptions. The former of the two words, however, requires some remarks.

In the first place, it is not generally admitted that -έας, from a nom. sing. -ής, has sprung from ένας. It is commonly supposed to be from έσας. The point suggested is,—that the Ur-Griechisch word now discovered is evidence that this supposition is not altogether correct. It is admitted that a compound adjective in -ής, the latter element of which is a noun in -ος -εος, such as δυσ-μενής, δι-ετής, would have originally formed its genitive in -έσος. Such a word would correspond to a Sanskrit noun in *âs*, as *dur-manâs*. But the question now raised is whether there may not be compounds, the last element of which is a verbal root, or a primary noun from which this is derived, to which the suffix *in* was attached as implying possession; and whether the *in* of such compounds has not become in the nominative -ής, -ές; so that these adjectival terminations are in some instances the equivalents of the Sanskrit adjectival terminations *î, i*. This is supposed by Dr. Hincks to have been the case in such instances as μυλο-ειδ-ής, ἀ-ληθ-ής, τρι-ήρ(εσ)-ής, &c.; the roots being ιδ (Ϝεδ), λαθ and ερες. The original form of the suffix implying possession he supposed to be *ith*, which was liable to pass both into *is* and into *in*. Thus, in the first person plural of active verbs the original form *meth*, written -μετ, -μεδ (retained in the passive, where we have in classical Greek -μεθα), became μεν and dialectically μες. It is this *th*, written in the old alphabet τ or δ, which is so apt to be dropped between vowels, and at the end of a word, and which in the latter position, if not dropped, must be changed into σ or ν. In reality, the root which is above written ερες was ερεδ, *ereth*.

The addition of the suffix *in*, implying possession, to a compound, is unusual in Sanskrit; but instances may be produced. One is, according to Bopp, *âmnâya-sârin*. In Lithuanian, however, a suffix is generally added to the compound. It appears in the present languages as *i*, which Bopp supposes to have been *ia*, but which may have been originally *in*. The usual form of a Lithuanian compound is *did-burn-is, rot-pon-is, tri-kamp-is*; *na-baga-s*, without the suffix, is spoken of by Bopp as exceptional.

This is one reason for supposing that the language to which these words belong was of Lithuanian origin. The suffix *in*, which appears not only in *ligwindinas*, but in the proper names nom. *Kustaspi*, gen. *Ligrakhinas*, may be connected with the Lithuanian *is* and the Greek ής, but is abhorrent to the genius of both the Sanskrit and Zend languages.

The difference between Ϝενδ and Ϝειδ seems also to require some observations. The root is Ϝεδ; and according to the custom of the Indo-European languages, and especially of the eastern family, or families of them, a nasal may be introduced between a short vowel and the consonant which follows it. The Greek ει and οϜ were in the old Cadmean alphabet the representatives of the long vowels *î* and *û*. They are equivalent to *iy* and *uw*, ι and Ϝ being in that alphabet semivowels; and these long vowels were substituted for ε and ο followed by a nasal, when that nasal was omitted. It is worthy of notice, however, that in the inscription on a broken obelisk in the British Museum, in the first column, where the king enumerates the animals that he had taken or killed, or rather designed to do so (blanks for the number being left before each name of an animal, which were never filled up), mention is made in the twenty-third line of "—— *ligwidini*" followed by the plural sign. The omission of the nasal in the word, as here written, shows that it was not essential. The plural sign after *ni* is here substituted for the Indo-European termination *nas*. Possibly *ligwidini* is intended for the nominative singular feminine; or it may be the nominative *ligwidi* with the Assyrian termination of the accusative plural.

The word *wida* is used in Old Prussian for "likeness;" *sta-wida* and *ka-wida* representing the Latin *talis* and *qualis*. This is another indication of a connexion between the languages to which these words belong, and the old Lithuanian.

A third indication of this is derived from the name *lâsanan*. As used in the Assyrian inscriptions, it denoted the Indo-European tribes on the west of Assyria;—those who called themselves by this name. Exactly in the same way, the Egyptians applied the name עמו to the Semitic tribes in whose language this word signified "the peoples." Now this word *lâsanan* was originally *lâthanan*; and while its stem is the same as that of the name of the Lithuanian people, it has other affinities, which are very remarkable. The Lydians, Λυδοί, were evidently a branch of the same people; notwithstanding the mythic derivation of their name given by Herodotus. But their identity with the *Lutan* or *Ludan* of the Egyptian inscriptions is equally certain, and still more important, as it shows us that for a considerable time before they pushed their conquests to the neighbourhood of Egypt (viz. to Mount Lebanon), they had been warring against them on their northern frontier, when their empire extended to Mesopotamia.

The termination of this name requires some remarks. It may be the Semitic-plural ending, which the Egyptians borrowed from those tribes which intervened between them and these *Ludan*; or it may be the accusative plural of the Indo-European name. It may be well, however, to compare it with the termination of another proper name, which occurs in the Sallier Papyrus No. 3, and which appears to refer to the very same people. A name is found there, which Champollion read *Iwan* and took for the *Ionians*. It has since been ascertained that the character which Champollion read *i* has for its value *ari* or *iri*. The name therefore is *Ariwan*, the Aryans or noble people, a title which the Indian and Persian branches of this people which descended from the north applied to themselves, and which (it would seem) the Syrian branch of the same people also used. The *an* at the end of these two names is probably the same element; and the fact of its being preceded by *w*, when not preceded by a consonant, suggests a third explanation of it. It may be the suffix which appears in *râjan* (nom. *râjâ*), *δαίμων*, *latron* (nom. *latro*) and *ahman* (nom. *ahma*), which suffix was probably the theme of the first numeral, denoting a noun of unity. Thus *Ariwan* would be *'Αρίων*, or *'Ιρίων*, from the latter of which it is just possible that *Ἴων* may be derived.

Whatever may be thought of this last derivation, it seems clear that the Indo-European glosses, found in the Assyrian inscriptions, are in the language of a people which had separated, some centuries before the date of the earliest Assyrian inscription, from the Aryans of Persia, and which had probably accompanied these in their migration from the northern region which they originally inhabited; and that while a portion of these western Aryans remained in Syria and the adjacent countries, the main body of them proceeded westward through Asia Minor and across the Bosphorus or Hellespont, forming the Hellenic or Ionic people of the Greeks; which mingled with the Pelasgians (a more ancient Indo-European race akin to the Italian tribes), and by their union formed the different dialects of Greek with which we are acquainted. It is probable, but not so certain, that the language of the people from whom all these Aryan tribes were derived, was Lithuanian in its oldest form.

A New Map of the Interior of the Northern Island of New Zealand, constructed during an Inland Journey in 1859. *By* Professor F. VON HOCHSTETTER (*Vienna*), *Geologist of the Austrian Novara Expedition.*

On the Antiquity of the Human Race. By Dr. J. HUNT.

On the Geographical Distribution and Trade in the Cinchona.

By V. HURTADO.

The different species of the tree which yields the bark known in commerce as Peruvian bark, and from which the sulphate of quinine is obtained, grow on the slopes of the Andes, at a height which varies according to the latitude and the topographical situation of the mountains where this precious vegetable production has been found. In New Grenada it grows on the central branch of the Cordillera, which extends from the province of Paito, and separates the two valleys of the Cauca and Magdalena, being most abundant in the districts of Pitayó and Almaguer. It is also found on the mountains above Finagamga, near Bogotá. The Pitayó bark has been the richest in quinine; and as in that locality the cuttings have been carried on to the greatest extent, the article is nearly exhausted. The same may be said of the Finagamga variety, which, although not so rich as the Pitayó, is prized on account of its being of easier labour. The Almaguer bark, which at first was hardly saleable, is now used to a great extent in Philadelphia and London, on account of the scarcity of the two former species. The best bark is found on the Pitayó mountain, at a height of from 8000 to 11,000 feet above the level of the sea. The tree grows among the numerous species of Alpine vegetation which cover those mountains with thick forests, either in clusters or scattered about. For that reason it varies in size. Like all trees of a cold climate, it is of slow growth, and requires a great many years to arrive at a good height. Some of them have been found so large as to yield forty *arrobas* of green bark, which, when dried up, is reduced to about a third of its weight. Others only produce about ten *arrobas*. As this tree is chiefly found in wild, cold, uninhabited mountains, constantly covered by clouds, there has been no system in cutting, nor any study made to ascertain how long a spot should be left at rest before undertaking new cuttings. It is known that the roots produce a great many shoots after a tree is cut down, and that these require about fifty years to become of a middling size. Young trees are also found growing from seeds. The nature of the soil seems to determine the qualities of the alkalies contained in the bark, quinine being most abundant in Pitayó, and cinchonine in Almaguer. But rocky mountains and ravines are the spots where nature has placed this vegetable species. The author is not aware that any bark trees have been found on the western Cordillera, which separates the valley of Cauca from the Pacific coast, which ridge never attains the elevation of perpetual snow in those latitudes. It only remains to state, that the price of good sound Pitayó bark, which had gone down in London to 1*s.* 8*d.* per pound, is now as high as 2*s.* 6*d.*, and some very inferior lots have been sold at 3*s.* The Almaguer sort, which was entirely neglected two years ago, is now accepted by manufacturers at from 1*s.* to 1*s.* 4*d.* per pound. No mention is made of the Bolivian bark, the most esteemed in commerce, as the author is not personally acquainted with that trade.

On Alphabets, and especially the English; and on a New Method of Marking the Sound of English Words, without change of Orthography. By the Rev. Professor JARRETT, *M.A.*

On the Origin of the Arts, and the Influence of Race in their Development. By R. KNOX.

A brief Account of the Progress of the Works of the Isthmus of Suez Canal. By D. A. LANGE.

On the Jaczwings, a Population of the Thirteenth Century, on the Frontiers of Prussia and Lithuania. By R. G. LATHAM, *M.D., F.R.S.*

In the middle of the thirteenth century, the Jaczwings were a powerful nation, between the Vistula, the Niemen, and the Upper Dnieper. At the present moment, a small population, called by the neighbouring Lithuanians *Jodwezhai*, and distinguished by a dark complexion and certain peculiarities of dress and manners, is the chief representative of the name. A few localities—(1) *Jatvis Pol=Jaczving Land*, (2) *Jatvis Stara=Old Jatvis*, (3) *Jatvis Nova=New Jatvis*, (4) *Mogilki-Jadzhvingowski=Jaczving Graves*, and (5, 6, 7) three villages named *Jatvesk*, complete the fragments. The name, having come to us through Latin, Polish, German, Bohemian, and Russian mediums, is hardly twice spelt alike, *e. g.* we have *Jazuingi, Jasuingi, Jacuingi, Jacwingi, Jaczwingi, Jatwingi* in the German and Polish; *Jatvyagi, Jatviazhi, Jatviezie*, &c., in the Russian. To these add *Getwezeu, Getuinzetæ*, and even *Getæ*. In speculating upon the ethnological affinities and the former extension of these tribes, in the direction of both the *Gothini* and the *Gothones* of the classical writers, this multiplicity of variations must be borne in mind. In respect to the immediate affinities of the nation at the particular time under notice, the evidence is very decided to their being members of the same family, and to their speaking the same language with the Prussians (*i. e.* the occupants of East Prussia before the German Conquest), the Lithuanians, the Samogitians, and the Letts. Their locality supports these statements, as do the few words which have come to us from their language. Whether they were equally Lithuanic in blood, is another question. The few, but important details of their history derive their interest (as do those of the Lithuanic family altogether) from the peculiar character of the great religious contest which they represent. With the Greek Christianity of Russia on the east, and the Papal influences on the west, Lithuania and Finland were not only the last strongholds of Paganism, but were acted upon as such in two directions. The resistance, however, of the Lithuanians was most obstinate; and the most obstinate of the Lithuanians were the Jaczwings. Their annihilation, too, was most complete. In 1264, a great battle broke their power. In the fifteenth century *not even the name of the*

Jaczwings remained. A more moderate notice simply says *that the name of the Jaczwings was very rare and known to few.* Conjointly with the special details of the Jaczwings themselves, those of the populations with which they came in contact should be studied—those of Russia and Poland, cut up into duchies; of Gallicia, a powerful principality; of Lithuania, a kingdom under Mindov, vacillating both in creed and politics; of North-Eastern Germany under the Knights of the Teutonic order; and, finally, of Volhynia occupied by Comanian Turks, and partly overrun by Mongols. Details, however, of this kind are beyond the pale of the present notice, which is chiefly made for the sake of drawing attention to the history of a nation—the pre-eminently Pagan nation of Europe—once powerful, but now fragmentary, the blood of which must still be found in more than one district where the language is German, Lithuanic, Polish, or Russian.

On the latest Discoveries in South-Central Africa.

By Dr. D. LIVINGSTONE.

The following letter from Dr. Livingstone was read to the Section:—

River Shiré, Nov. 4, 1859.

The River Shiré has its source in the green waters of the great Lake Nyassa (lat. 14° 23′ S., long. 35° 30′ E.). It flows serenely on in a southerly direction, a fine navigable stream, from 80 to 120 yards in breadth, expanding some 12 or 15 miles from Nyassa into a beautiful lakelet, with a well-defined water horizon, and perhaps 5 or 6 miles wide; then narrowing again, it moves quietly on about 40 miles, till it reaches Murchison's Cataracts. After a turbulent course of 30 miles, it emerges from the cataracts a peaceful river capable of carrying a large steamer through the remaining 112 miles of its deep channel, and joins the Zambesi in lat. 17° 47′ S., 100 miles from the confluence of that river with the sea. The valley through which the Shiré flows is from 10 to 12 miles broad at the southern extremity of Lake Nyassa, but soon stretches out to 20 or 30 miles, and is bounded all the way on both sides by ranges of hills, the eastern range being remarkably lofty. At Chihisas (lat. 16° 2′ 3″ S., 35° 1′ E.), a few miles below the cataracts, the range of hills on the left bank of the Shiré is not above 3 miles from the river, while the other range has receded out of sight. If from Chihisas we proceed in a north-easterly path, a three hours' march places us on an elevation of upwards of 1000 feet. This is not far from the level of the Upper Shiré valley (1200 feet), and appears to be its prolongation. Four hours' additional travel, and we reach another plateau, 1000 feet higher, and in a few hours more the highest plateau, 3000 feet above the level of the sea, is attained, and we are on an extensive table-land, which, in these three distinct divisions, extends to Zomba (lat. of southern end 15° 21′ S.). It is then broken; and natives report that, north of Zomba, which is 20 miles in length from north to south, there is but a narrow partition between Lakes Nyassa and Tamandua (Shirwa). Three islands were visible on the west side of what we could see of Nyassa from its southern end. The two ranges of hills stretch along its shores, and we could see looming through the haze caused by burning grass all over the country the dim outlines of some lofty mountains behind the eastern hills. On the table-land are numerous hills and some mountains, as Chicadgura, perhaps 5000 feet high, and Zomba (which was ascended), from 7000 to 8000 feet in altitude. From this table-land we can see, on the east of Lake Tamandua, the Milanje Mountains, apparently higher than Zomba and Mount Clarendon, not unworthy of the noble name it bears. All this region is remarkably well-watered; wonderfully numerous are the streams and mountain rills of clear, cool, gushing water. Once we passed eight of them and a strong spring in a single hour, and we were then at the end of the dry season. Even Zomba has a river about 20 yards wide, flowing through a rich valley near its summit. The hill is well wooded also; trees, admirable for their height and the amount of timber in them, abound along the banks of the streams. "Is this country good for cattle?" the head man of the Makololo, whose business had been the charge of cattle, was asked. "Truly," replied he; "don't you see the abundance of such and such grasses, which cattle love, and on which they grow fat?" And yet the people have only a few goats, and still fewer sheep. There are no wild animals in the highlands, and but few birds; and with the exception of one place, where we saw some elephants, buffaloes, &c., there are none on the plains of the Upper Shiré, but the birds, new and strange, are pretty numerous. In the upper part of the Lower Shiré, in the highlands, and in the valley of the Upper Shiré, there is a somewhat numerous population. The people generally live in villages and in hamlets near them. Each village has its own chief, and the chiefs in a given territory have a head chief, to whom they owe some sort of allegiance. The paramount chief of one portion of the Upper Shiré is a woman, who lives two days' journey from the west side of the river, and possesses cattle. The chief has a good deal of authority; he can stop trade till he has sold his own things. One or two insisted on seeing what their people got for the provisions sold to us. The women drop on their knees when he passes them. Mongazi's wife went down on her knees, when he handed her our present to carry into the hut. One evening a Makololo fired his musket without leave, received a scolding, and had his powder taken from him. "If he were my man," said the chief, "I would fine him a fowl also." The sites of their villages are selected, for the most part, with judgment and good taste. A stream or spring is near, and pleasant shade-trees grow in and around the place. Nearly every village is surrounded by a thick high hedge of the poisonous Euphorbia. During the greater part of the year the inhabitants could see an enemy through the hedge, while he would find it a difficult matter to see them. By shooting their already poisoned arrows through the tender branches, they get smeared with the poisonous milky juice, and inflict most painful if not fatal wounds. The constant dripping of the juice from the bruised branches prevents the enemy from attempting to force his way through the hedge, as it destroys the eyesight. The huts are larger, stronger built, with higher and more graceful roofs than any we have seen on the Zambesi. The Boabab (spreading place) is at one side of the village; the ground is made smooth and level, and the banians, the favourite trees, throw a grateful shade over it. Here the people meet to smoke tobacco and *bang*; to sing, dance, beat drums, and drink beer. [In the Boabab of one small village we counted fourteen drums of various sizes, all carefully arranged on dry grass.] Some useful work, too, is performed in this place, as spinning, weaving, making baskets and fish-nets. On entering a village, we proceeded at once to the Boabab, on which the Strangers' hut is built, and sat down. Large mats of split bamboo are politely brought to us to recline on. Our guides tell some of the people who we are, how we have behaved ourselves since they knew us, where we are going, and what our object is. This word is carried to the chief. If a sensible man, he comes as soon as he hears of our arrival; if timid or suspicious, he waits till he has thrown his dice, and given his warriors, for whom he has sent in hot haste, time to assemble. When the chief makes his appearance, his people begin to clap their hands, and continue clapping until he sits down; then his councillors take their places beside him, with whom he converses for a minute or so. Our guides sit down opposite them. A most novel scene now transpires; both parties, looking earnestly at each other, pronounce a word, as "Amhinatu" (our chief or father), then a clap of the hands from each one—another word, two claps—a third word, three claps—and this time all touch the ground with their closed hands. Next, all rise clapping—sit down again, and—clap, clap, clap—allowing the sound gradually to die away. They keep time in this most perfectly, the chief taking the lead. The guides now tell the chief all they please, and retire, clapping the hands gently, or with one hand on the breast; and his own people do the same, when they pass the chief, in retiring. The customary presents are exchanged, after a little conversation with the chief, and in a short time his people bring provisions for sale. In some villages the people clapped with all their might when they approved what the chief was saying to us. In others, the clapping seems omitted in our case, though we could see it was kept with black strangers who came into the village. The chief at the Lake, an old man, came to see us of his own accord,—said he had heard that we had come, and sat down under a tree,—and he came to invite us to take up our quarters with him. Many of the men are very intelligent-looking, with high foreheads and well-shaped heads. They show singular taste in the astonishingly varied styles in which their hair is arranged. Their bead necklaces are really pretty specimens of work. Many have the upper and middle as well as the lower part of the ear bored, and have from three to five rings in each ear. The hole in the lobe of the ear is large enough to admit one's finger, and some wear a piece of bamboo about an inch long in it. Brass and iron bracelets, elaborately figured, are seen; and some of the men sport from two to eight brass rings on each finger, and even the thumbs are not spared. They wear copper, brass, and iron rings on their legs and arms; many have their front teeth notched, and some file them till they resemble the teeth of a saw. The upper lip ring of the women gives them a revolting appearance; it is universally worn in the highlands. A puncture is made high up in the lip, and it is gradually enlarged until the pelelé can be inserted. Some are very large. One we measured caused the lip to project two inches beyond the tip of the nose; when the lady smiled the contraction of the muscles elevated it over the eyes. "Why do the women wear these things?" the venerable chief, Chinsurdi, was asked. Evidently surprised at such a stupid question, he replied, "For beauty! They are the only beautiful things women have; men have beards, women have none. What kind of a person would she be without the pelelé? She would not be a woman at all with a mouth like a man, but no beard." One woman having a large tin pelelé with a bottom like a dish, refused to sell it, because, she said, her husband would beat her if she went home without it. These rings are made of bamboo, of iron, or of tin. Their scanty clothing—the prepared bark of trees, the skins of animals (chiefly goats), and a thick strong cotton cloth—are all of native manufacture. They seem to be an industrious race. Iron is dug out of the hills, and every village has one or two smelting houses; and from their own native iron they make excellent hoes, axes, spears, knives, arrow-heads, &c. They make, also, round baskets of various sizes, and earthen pots, which they ornament with plumbago, said to be found in the Hill Country, though we could not learn exactly where, nor in what quantities: the only specimen we obtained was not pure. At every fishing village on the banks of the river Shiré men were busy spinning buaze and making large fishing-nets from it; and from Chihisas to the Lake, in every village almost, we saw men cleaning and spinning cotton, while others were weaving it into strong cloth in looms of the simplest construction, all the processes being excessively slow. This is a great cotton-growing country. The cotton is of two kinds, "Tonji manga," or foreign cotton; and "Tonji cadji," or native cotton. The former is of good quality, with a staple from three-quarters to an inch in length. It is perennial, requiring to be re-planted only once in three years. The native cotton is planted every year in the highlands, is of short staple, and feels more like wool than cotton. Every family appears to own a cotton patch, which is kept clear of weeds and grass. We saw the foreign growing at the Lake and in various places for 30 miles south of it, and about an equal number of miles below the cataracts on the Lower Shiré. Although the native cotton requires to be planted annually in the highlands, the people prefer it, because, they say, "it makes the stronger cloth." It was remarked to a number of intelligent natives near the Shiré lakelet, "You should plant plenty of cotton, and perhaps the English will come soon and buy it." "Surely the country is full of cotton," said an elderly man, who was a trader and travelled much. Our own observations convinced us of the truth of this statement. Everywhere we saw it. Cotton patches of from 2 to 3 acres were seen abreast of the cataracts during the first trip, when Lake Tamandua was discovered, though in this journey, on a different route, none were observed of more than half an acre. They usually contained about a quarter of an acre each. There are extensive tracts on the level plains of both the Lower and Upper Shiré, where salt exudes from the soil. Sea island cotton might grow well there, as on these the foreign cotton becomes longer in the staple. The cotton-growers here never have their crops cut off by frosts. There are none. Both kinds of cotton require but little labour, none of that severe and killing toil requisite in the United States. The people are great cultivators of the soil, and it repays them well. All the inhabitants of a village, men, women, and children, and dogs, turn out at times to labour in the fields. The chief told us all his people were out hoeing, and we saw in other parts many busy at work. If a new piece of ground is to be cultivated, the labourer grasps as much of the tall dry grass as he conveniently can, ties it into a knot at the top, strikes his hoe through the roots, detaching them from the ground with some earth still adhering, which, with the knot, keeps the grass in a standing position. He proceeds in this way over the field. When this work is finished, the field exhibits a harvest-like appearance, being thickly dotted all over with these shocks, which are 3 feet high.

A short time before the rains several of these shocks are thrown together, the earth scraped over them, and then the grass underneath is set on fire. The soil is thus treated in a manner similar to that practised in modern times among ourselves on some lands. When they wish to clear a piece of woodland, they proceed in precisely the same way as the farmers in Canada and the Western States do,—cut the trees down with their axes, and, leaving the stumps about 3 feet high standing, pile up the logs and branches for burning. They grow lassaver in large quantities, preparing ridges for it from 3 to 4 feet wide, and about a foot high. They also raise maize, rice, two kinds of millet, beans, sugar-cane, sweet potatoes, yams, ground-nuts, pumpkin, tobacco, and Indian hemp. Near Lake Nyassa we saw indigo 7 feet high. Large quantities of beer are made, and they like it well. We found whole villages on the spree, and saw the stupid type of drunkenness, the silly sort, the boisterous talkative sort, and on one occasion the almost up-to-the-fighting-point variety, when a petty chief, with some of the people near, placed himself in front, exclaiming, "I stop this path; you must go back." Had he not got out of the way with greater speed than dignity, an incensed Makololo would have cured him of all desire to try a similar exploit in future. It was remarked by the oldest traveller in the party that he had not seen so much drunkenness during all the years he had spent in Africa. The people, notwithstanding, attain to a great age. One is struck with the large number of old grey-headed persons in the highlands. This seems to indicate a healthy climate; for their long lives they are not in the least indebted to frequent ablutions. "Why do you wash yourselves? our men never do," said some women at Chinsurdi to the Makololo. An old man told us he remembered having washed himself once when a boy, but never repeated it; and from his appearance one could hardly call the truth of his statement in question. A fellow who volunteered some wild geographical information followed us about a dozen miles, and introduced us to the chief Moena Moezi by saying, "They have wandered; they don't know where they are going." "Scold that man," said a Makololo head to his factotum, who immediately commenced an extemporary scolding; yet the singular geographer would follow us, and we could not get quit of him till the Makololo threatened to take him to the river and wash him. The castor-oil with which they lubricate themselves and the dirt serve as additional clothing, and to wash themselves is like throwing away the only upper garment they possess. They feel cold and uncomfortable after a wash. We observed several persons marked by the small-pox. On asking the chief Mongazi—who was a little tipsy, and disposed to be very gracious,—if he knew its origin, whether it had come to them from the sea, "He did not know," he said, "but supposed it must have come to them from the English." Like other Africans, they are somewhat superstitious. A person accused of bewitching another and causing his death, either volunteers or is compelled to drink the Maiori, or ordeal. On our way to the lake a chief kindly led us past the next two villages, whose chiefs had just been killed by drinking the Maiori. When a chief dies his people imagine that they may plunder any stranger coming into their village. A chief, near Zomba, at whose village we took breakfast on our way up, drank the Maiori before our return, and vomiting, was therefore innocent. His people we found manifesting their joy by singing, dancing, and beating drums. Even Chibisa, an intelligent and powerful chief, drank it once, and when insisting that all his numerous wars were just, and that his enemies were always in the wrong, said to us, "If you doubt my word, I am ready to drink the Maiori." On the evening of the day we reached Moena Moezi, an alligator carried off his principal wife from the very spot where some of us had washed but a few hours before. We learned on our return that he had sent messengers to several villages, saying, "He did not know whether we had put medicine on the spot, but after we had been there his wife was carried off by an alligator." The first village refused to sell us food, would have nothing whatever to do with us, and the chief of the next village, who happened to be reclining in the Boabab, ran off, leaving his wooden pillow and mat behind. The women seldom run away—having more pluck perhaps than the men. When a person dies, the women commence the death-wail, and keep it up for two days. A few words are chanted in a plaintive voice, ending by a prolonged note: *a—a*, or *o—o*, or *ea, ea, e—a*. The corpse is buried in the same hut in which he dies. It is then closed up and allowed to fall into decay. We found one village in mourning, on the banks of the Upper Shiré. The chief's father had died some time previous. They had not washed themselves since, though washing is practised more or less on these plains; and they would not wash until some friends at a distance, who possessed muskets, had come and fired over the grave. The badge of mourning consists of narrow strips of Palmyra leaf, tied round the head and arms, sometimes round head, neck, breast, knees, ankles, arms, and wrists. They have the idea of a Supreme Being, whom they name Pambé, and also of a future state. The chief Chinsurdi said they all knew that they lived again after death. "Sometimes the dead came back again,—they appeared to them in dreams, but they never told them where they had gone to." This is an inviting field for benevolent enterprise. There are thousands needing Christian instruction, and here are materials for lawful commerce, and a fine healthy country, with none of the noxious insects with which Captains Burton and Speke were tormented, and, with the single exception of 30 miles, water communication all the way to England. Let but a market be opened for the purchase of their cotton, and they can raise almost any amount of it, and the slave trade will speedily be abolished.

On the Mountain Districts of China, and their Aboriginal Inhabitants.
By W. LOCKHART.

Much of the empire of China with which we are best acquainted, consists of the plains that lie near the mouths of the rivers, as they find their way to the sea-board, and it is here that the important ports for our trade are situated. The interior of the country is richly diversified; the land rises considerably towards the hilly districts, that slope from the chains of mountains that traverse all the western provinces and spread themselves out through the central part of the country, being in fact the eastern spurs of the Kwan-lun and Himalaya ranges, that rise in Northern India to a vast height, and gradually pass down through the north and south of Tibet towards China. The Kwan-lun range passes into the northern and central provinces of China, and the Himalaya into the southern and south-western provinces, while the Tien-shan or Celestial Mountains and the Altai chain pass into Mongolia and Mantchouria, commonly called Chinese Tartary.

In the mountainous regions of China the country is very beautiful, and combines the varieties of scenery found in other similar districts; many of these portions of the empire are brought into communication with the sea coast, by means of the large rivers that flow through all the rich and fertile central provinces, offering great facility for the interchange of the various commodities of different parts of the empire. These rivers form in fact the high roads of the country.

For purposes of communication in the mountain districts, and to facilitate the transit of goods, many roads have been cut at great expense and with much labour over the passes between the high ridges. The great road from Pekin to the southwest through Shen-si to Sze-chuen, is by a mountain route, which required great ability and skill to make passable; many years were spent in this work, and it is a monument of the patience and perseverance by which it was accomplished; by this road merchants and officers constantly travel between the capital and the western frontier. The road from Shan-si to Kan-suh is one of the most extensive works of the kind in China. Besides these great trunk roads, there are several other mountain routes, by which goods are carried from province to province across the mountains, one of which may be mentioned, as the well-known Mei-ling pass between Kwang-tung and Kiang-si; it is 24 miles long, and over it all the tea and silk that go to Canton are carried on men's shoulders. Much might be said regarding these mountain roads of China, but it is impossible to enter on the subject here.

It is among these mountains and in the valleys they enclose, that many tribes of people dwell who are probably the aborigines or natives of the land. The great mass of the people who inhabit China are those who dwell in the cities and villages, cultivating the land, following the pursuits of commerce, and acknowledging the authority of one emperor; these may be considered to be the Chinese of the present day; but in the islands of Formosa and Hainan, as well as in the western frontier, dwell those native savage tribes, who acknowledge no submission to the Emperor of China, dwell among their own hills, and have ever maintained their independence.

The island of Formosa is divided from north to south by a chain of mountains that cuts the island in two. On the western side live the Chinese, who passing from the opposite coast of Fuh-kien, have gradually driven away the aborigines to the eastern side; some barter is kept up between these two parties, but they are generally in a state of hostility, and constant vigilance is required on the part of the Chinese to guard against the attacks of the natives, and this interferes very much with their intercourse. The natives are governed by their own chiefs, who keep up a kind of government. The occupations are tilling the ground, working in the mines in the mountains, weaving coarse cloth, fishing, and washing the sand of certain districts for gold.

The *Aurelia Papyrifera*, from the pith of which *rice paper* is made, grows in Formosa. These native tribes also inhabit the mountain districts of the island of Hainan. The Chinese live on the eastern coast, where they have large fishing stations, for the supply of Southern China with salt fish; and the natives dwell by themselves on the western side, and maintain their independence and separation from the intruders on their coast.

The mountainous regions of the Nan-ling and Mei-ling between Kwang-si and Kwei-chau give lodgment to many clans of these aborigines, who are called Miau-tsze, or "children of the soil," which they no doubt are. It is singular that any of these people should have maintained their independence so long and not been compelled to submit to Chinese rule, surrounded as they are by the Chinese people. This race presents so many physical points of difference to the Chinese, as to lead me to infer that they are a more ancient people than the latter, and the aborigines of Southern China. They are smaller in size and stature than the Chinese, have shorter necks, and their features are more angular. The degree of civilization they have obtained is much below that of the Chinese. It is not known what language they speak, but the names given to the parts of the body and the common articles about their boats, by some boatmen who visited Canton some years since, showed that it was evidently not Chinese.

There are about forty tribes of these Miau-tsze scattered over the mountains of Kwang-tung, Kwang-si, Hu-nan, and Kwei-chau, speaking several dialects, and differing among themselves in their customs, government, and dress. The Chinese government keep troops at the foot of the mountains to restrain these tribes, who, though often hostile, are on the whole inclined to live at peace, but resist every attempt to penetrate into their fortresses. The tribes are often at strife among themselves, which becomes a source of safety to the Chinese, who are ill able to resist these hardy mountaineers. It would appear that the race called the Chinese people, spreading over the magnificent country they had found, drove back the Miau-tzse or "sons of the soil," those on the coast taking refuge on the islands of Formosa and Hainan, while those to the westward sought their homes among the mountains in their neighbourhood; and there they have remained a separate people, divided into various tribes, ruled over by governors or chiefs of their own; the larger number of these Miau-tsze have maintained their independence, but some have taken office in the Imperial army, and have associated themselves with the Chinese. Various opinions are entertained as to the religious doctrines of these Miau-tsze, who appear not to be wholly idolaters; some of the tribes have a tradition of a Supreme God, who created the world, but their knowledge is very indistinct and imperfect. The chief source of information about these people is derived from a series of coloured drawings; one of the most perfect of such series that has been obtained was exhibited in the Section; the drawings were evidently taken by some Chinese traveller who visited the mountain tribes. Each drawing illustrates one of the tribes, and presents a group of the people in some characteristic occupation or amusement, and is accompanied by a short description of the tribe to which it refers.

These people are interesting from the fact that they must have a variety of ancient customs among them, and also because they are the sons of freedom; and however great may be the difference between us and them, they have a certain affinity with us, and may some day bid us a hearty welcome to the land of their forefathers. They are dispersed over the mountains of Southern and Central China, and live in a changeable state of relationship to the Chinese around them; sometimes they fight in open war, at others they rob and plunder, and sometimes they buy and sell.

These Miau-tsze live to a great extent on the eastern slopes of the mountains, whose western slopes, in South-Eastern Asia, are peopled by the numerous tribes of Laos and Shans, and more particularly of the Karens, who are our tried and faithful adherents in the territory of Burmah; and there are probably strong marks of similarity of origin and identity of race between the Miau-tsze of China and the Karens of Burmah and Pegu.

Journey in the Yoruba and Nupé Countries. *By* D. May, *R.N.*

History of the Ante-Christian Settlement of the Jews in China.
By Dr. Macgowan, *U.S.*

Cruise in the Gulf of Pe-che-li and Leo-tung (*China*). *By* J. Mickie.

On the Formation of Oceanic Ice in the Arctic Regions.
By Captain Sherard Osborn, *R.N., F.R.G.S.*

On the Course and Results of the British North American Exploring Expedition, under his Command in the years 1857, 1858, 1859. *By* Captain J. Palliser.

The first part of this paper was occupied with a sketch of the course of the expedition, illustrated by a large map. Starting from England in May 1857, the expedition reached Lake Superior by New York and the United States, from whence they travelled in canoes to the Red River settlement, then with horses and carts across the Plains to the north-west to Carlton, where the first winter was spent. During that season Captain Palliser travelled back to the States on business, and Dr. Hector reached as far west as the Rocky Mountains. In June 1858 the expedition resumed its westward course, and in August reached the line of the Rocky Mountains. The remaining two months before the winter set in was occupied in exploring the Mountains, resulting in the discovery of four passes. The second winter was spent at Edmonton, where the expedition reassembled in October. Captain Blakiston returned to England from this place. The winter of 1858–59 was spent in various explorations into the Rocky Mountains with the purpose of learning their winter aspect. The furthest of them reached almost to Mount Brown. In spring of 1859 M. Bourgeau returned to England, his term of engagement having expired; and the rest of the party, accompanied by two English gentlemen, the late Captain Brisco and Mr. Mitchell, proceeded through the Blackfoot country along the South Saskatchewan and boundary line, till in August they again separated to explore the mountains; Captain Palliser and Mr. Sullivan undertaking the west slope, and Dr. Hector to endeavour to pass direct to the valley of Fraser River. The party again rejoined at Fort Colvile, and from thence descended the Columbia river to the sea. A necessary delay at Vancouver Island allowed of a visit to the coal mines at Nanaimo, and also to Fraser River, after which the expedition returned to England by California, Panama, and the West Indies, having been absent exactly three years.

The territory which has now been examined and mapped by this expedition ranges from Lake Superior to the eastern shore of the lesser Okanagan Lake, and from the boundary line to the watershed of the Arctic Ocean. This large belt of the continent was explored in three seasons.

The first season was devoted to the examination of its south-eastern portion between Lake Superior to the elbow of the south branch of the Saskatchewan, and from the British boundary line or 49th parallel to Fort Carlton, in lat. 52° 52′ N., long. 106° 18′ W.

The second season was devoted to the examination of the territory between the two Saskatchewans, to the exploration of the Rocky Mountains, and to the discovery of the passes available for horses in the British territory.

The third season commenced with a long journey from our winter quarters at Edmonton in lat. 53° 34′ N., long. 113° 20′ W., through the Blackfoot country to the most western point in the neighbourhood of the boundary line, previously reached by the expedition from the eastward in 1857. A westward course was then resumed along the country between the South Saskatchewan and the British boundary line, thence once more across the Rocky Mountains. Finally, the connexion of a route practicable for horses was effected the whole way from Red River settlement across the continent to the Gulf of Georgia, entirely within British dominions.

This large belt of country embraces districts, some of which are valuable for the purposes of the agriculturist, while others will for ever be comparatively useless.

The extent of surface drained by the Saskatchewan, and other tributaries to Lake Winipeg, which we had an opportunity of examining, amounts in round numbers to 150,000 square miles. This region is bounded to the north by what is known as the "strong woods," or the southern limit of the great circum-arctic zone of forest, which occupies these latitudes in the northern hemisphere. This line, which is indicated in the map, sweeps to the north-west from the shore of Lake Winipeg, and reaches its most northernly limit about 54° 30′ N., and long. 109° W., from where it again passes to south-west, meeting the Rocky Mountains in lat. 51° N., long. 115° W. Between this line of the "strong woods" and the northern limit of the true prairie country there is a belt of land varying in width, which at one period must have been covered by an extension of the northern forests, but which has been gradually cleared by successive fires.

It is now a partially wooded country, abounding in lakes and rich natural pasturage, in some parts rivalling the finest park scenery of our own country. Throughout this region the climate seems to preserve the same character, although it passes through very different latitudes, its form being doubtless determined by the curves of the isothermal lines. Its superficial extent embraces about 65,000 square miles, of which more than one-third may be considered as at once available for the purposes of the agriculturist. Its elevation increases from 700 to 3500 feet as we approach the Rocky Mountains, consequently it is not equally adapted throughout to the cultivation of any one crop; nevertheless at Fort Edmonton, which has an altitude of 2000 feet, even wheat is sometimes cultivated with success.

The least valuable portion of the prairie country has an extent of about 80,000 square miles, and is that lying along the South Saskatchewan, and southward from thence to the boundary line, while its northern limit is known in the Indian languages as "the edge of the woods," the original line of the woods before invaded by fire.

On the western side of the Rocky Mountains, in the country which we examined, there were but few spots at all fitted for the agriculturist, and these form isolated patches in valleys separated by mountain ranges.

As the next result of our explorations, I shall briefly mention the different passes through the Rocky Mountains which we explored, alluding to the chief advantages and disadvantages of each.

The Kananaskis Pass and the British Kootanie Pass were examined by myself. Of these I consider the Kananaskis Pass the preferable one, both on account of its direct course through the mountains and its easier ascent.

The ascent to the height of land from the east is through a wide gently sloping valley, and the immediate watershed is formed by a narrow ridge, which, if pierced by a short tunnel, would reduce the summit level to about 4600 feet above the sea. The descent to the west, into which Kananaskis Pass opens, is comparatively easy.

The British Kootanie Pass also opens out into the Kootanie River valley, but the altitude here to be overcome is much greater, amounting to 6000 feet. There are likewise two ridges to be passed, which fact would form a very strong objection to this pass.

The Vermilion Pass, which was traversed by Dr. Hector, presents on a whole the greatest natural facilities for crossing the mountains without the aid of engineering work, as the rise to the height of land is gradual from both sides, a feature which seems to be peculiar to this pass. It would thus be impossible to diminish its summit level (which is less than 5000 feet), as is proposed in the case of Kananaskis Pass, but on the other hand it would be the most suitable for the construction of an *easy waggon road*.

This, like the other two passes I have mentioned, also strikes the Kootanie River close to its source; but last summer Dr. Hector crossed the mountains by another pass from the head of the north branch of the Saskatchewan, directly to the Columbia River, in the vicinity of the boat encampment.

Leaving this latter pass out of consideration for the present, as all of the others open to the Kootanie River, it becomes necessary to consider the course by whch it may be practicable to reach the coast of the Pacific without crossing to the south or American side of the boundary line. It was with great difficulty for this purpose even a partial examination of the country could be effected, owing to the rugged valleys which intersect it in a direction parallel to the mountains, and which, though not formidable themselves, are covered with such dense forest as to present obstacles to the traveller. Notwithstanding these difficulties, Mr. Sullivan succeeded in making his way on the north side of the boundary line, and at the same time following a system of transverse valleys, which might allow of the construction of a road without much trouble from the mouth of Kananaskis Pass to the Columbia, above Fort Colvile. From this point westward I myself ascertained that it would be possible to reach the valley of the Okanagan, by which I believe the Americans have already commenced to connect the waggon road of the Columbia with the upper country of the Frazer River. While pointing out the circumstances that seem to favour the possibility of carrying a road through British territory, from the Saskatchewan to the Pacific, I wish to refrain from expressing any opinion as to the expediency of undertaking at the present time a work which would involve a vast amount of labour and a corresponding heavy expenditure. For how long a time in the year such a road would remain open, is a question as yet unanswered, and which has a most important bearing on the subject. In addition, the difficulty of direct communication between Canada and the Saskatchewan country, as compared with the comparatively easy route through the United States by St. Paul's, renders it very unlikely that the great work of constructing a road across the continent can be solely the result of British enterprise.

Not the least important results of the expedition are the meteorological observations, which have been carefully conducted during the whole period of the explorations, both in the winters and summers, whether we were stationary or travelling. I lay stress upon this fact, as it affords materials for ascertaining the exact nature of the climate, and means for a correct comparison between its nature and that of Canada.

The hourly magnetic observations were conducted by Lieutenant Blakiston, R.A., assisted by the other members of the expedition, during the winter of 1857–58. These were not, however, carried on during the winter 1858–59, owing to the return of Lieutenant Blakiston with the instruments; the magnetic declinations however were attended to.

The astronomical observations and computations were placed in the hands of Mr. Sullivan, and the geographical position of the several salient points of the map are determined principally by his lunars, the rates of chronometers being, of course, too unsteady to be depended on while travelling through so rough a country.

The large botanical collection of our botanist, M. Bourgeau, has already been sent to Kew Gardens, where the specimens have been carefully arranged by himself under the inspection of Dr. Hooker, who highly values them.

Dr. Hector's specimens of fossils, &c. were from time to time transmitted to Sir Roderick Murchison at the Jermyn Street Museum, but from the nature of the subject much time must elapse before the results can be laid before Her Majesty's Government.

In conclusion, I have great pleasure in bearing testimony to the unceasing zeal and energy of my companions, whose valuable assistance has been instrumental in bringing the expedition to so successful a termination.

ADDENDUM 1.—*Remarks concerning the Climate of the Saskatchewan District. By* DR. HECTOR.

The winter temperature is about 21° Fahr., ranging, however, in regular successions from high to low temperatures. In January 1858 it was as high as 40° above zero for a few hours, accompanied by rain and high wind *. In that instance, however, between 4 P.M. and 9 P.M. it fell from +37° to −13, a difference of 50° in five hours. The greatest depression of the thermometer in both years was about the 12th of February. Throughout the winter the snow falls in storms, which seldom last more than two to three days. The first fall generally occurs in the month of October, but that always disappears again before the snows of November commence, which are permanent for the winter. From the open country the snow evaporates very rapidly, so that the prairies are never deeply covered; but in the woods it accumulates till spring. In some districts of the country more snow falls than in others; for instance, at Fort Pitt, about 400 miles east of the mountains, there is generally 3 feet to 4 feet of snow in spring, while close along the eastern base of the Rocky Mountains it seldom exceeds 6 inches, and disappears very early. At Fort Edmonton the snow always disappears fully a fortnight sooner than at Fort Pitt, although both places are in the same latitude, but the former 3° further to the west.

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* January 3rd, 1858, at Fort Edmonton.

The rivers generally freeze up about the 12th of November, and it is curious that the Saskatchewan "*takes*," as the local term has it, on the same day both at Edmonton and Carlton, places distant from one another nearly 500 miles. In 1858 the ice broke up on the 7th of April, but in 1859 not till the 26th of that month. But this does not show the whole of the remarkable difference in those two seasons; for in the former the ice rotted away gradually, while in the latter it "*gave*" in a single night from a sudden flood which followed the first warm weather.

A spring season hardly exists in the Saskatchewan, for in a few days everything bursts into full verdure after the breaking up of winter. June is generally a wet month; and much rain also falls during the first half of July, but after that period the summer is very dry. There is little or no thunder in the higher country, unlike the Red River settlement, where for a certain season thunder-storms are of daily occurrence.

The nature of the snow-line on the Rocky Mountains gives a clew to the climatal arrangement of the country to the east. Although there are many of the mountains in the eastern part of the range which exceed those to the west in altitude, only few of their valleys are filled with glaciers. The great glaciers at the source of the north branch of the Saskatchewan are fed from fields of ice and perpetual snow, that may be considered as lying on the western slope of the range. The diminished altitude of the snow-line towards the west is thus proved. The reason is, that the prevailing winds are from the west, and in rising to cross the mountains they are cooled, and so deprived of their moisture, which ceases to be deposited after they pass over the greatest altitude.

Concerning the Indians of the west side of the mountains, he stated that the tribes are very numerous, and principally support themselves on fish. In most of the tributaries of the Columbia the salmon swarm in such numbers as to taint the air at a certain season of the year when their bodies are cast up on the banks. These fish-eating Indians are of very low grade, as wherever Indians obtain their living easily they invariably become debased. Thus the Indians to the east of the Rocky Mountains, that dwell in the strong woods, and live by the chase of animals, such as the Moose-deer, which requires great skill and sagacity, are vastly superior to the Indians of the plains, who, living on buffalo, with ease obtain abundance of food.

He adduced the case of the Sarcees, who belong to a tribe of M^cKenzie River Indians, called the Chepeyans, who are perhaps the finest Indians on the continent; and yet these Sarcees, from having left their natural course of life some centuries back, and taken to the plains, where they live among the Blackfoot tribes, have become the worst Indians of the Saskatchewan. Their constitutions have become enfeebled, as is shown by the prevalence of goitre among them, the whole tribe being affected with this disease almost without exception, whereas it seldom or never occurs among other Indians. The half-breeds who live in the Forts of the Upper Saskatchewan are very subject to goitre, the cause for which is very obscure.

ADDENDUM 2.—*Remarks concerning the Tribes of Indians inhabiting the Country examined by the Expedition.* *By* MR. SULLIVAN.

Mr. S. pointed out that the northern portion was occupied by the Crees, which are the most prominent tribe of the country, and best known to white men. The district along the South Saskatchewan and towards the boundary line, he stated was inhabited by a collection of allied tribes, all speaking nearly the same language, and known as the Blackfoot. This term comprises the Blackfoot proper, the Blood Indians, Peagans, Gro Ventres, Sarcees, and several others. The Sarcees, however, are really very different Indians, and have their relations far to the north on M'Kenzie River. He next spoke concerning the languages of the tribes, of which he has prepared vocabularies, stating that that of the Crees is very perfect, having a very effective system of grammar, which has been ably developed by the missionaries, who have also invented a system of syllabic characters, by which the Indians soon learn to read and write in their own language. These characters could also be applied to all the other Indian languages he examined east of the mountains, excepting Sarcee, which is too guttural.

He remarked that a very interesting, though small tribe, known as the Mountain Stoneys, had been induced by the Wesleyan missionary to commence a little agriculture. It does not amount to much, however, their principal crop being turnips, which they generally pull and eat raw before they are nearly grown. Of the very different habits of Indians which inhabit the woods from those of the plains, he mentioned in addition the curious circumstance, that in a camp of the former Indians there is never any noise; and even in conversation they talk almost at an inaudible pitch, a habit derived from their stealthy habits in hunting; whereas a camp of Plain Indians resembles a fair, as drums beating, whooping, and singing is continued all day and all night.

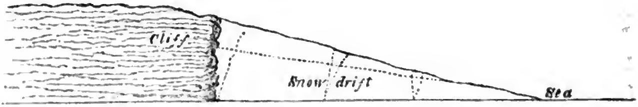
On his proposed Journey from Khartum in Upper Egypt to meet Captain Speke *on or near the Lake Nyanza of Central Africa. By* Consul PETHERICK.

On the Formation of Icebergs and Ice Action, as observed in the Hudson's Bay and Straits. By Dr. J. RAE.

The manner in which icebergs are generally formed is so well known that it would be out of place to mention it here, but I have observed in Hudson's Bay and Straits these ice-islands formed in a mode different from that usually described.

Along these shores there are high and steep cliffs fronting the sea, and having deep water at their base. Many of these cliffs face to the south-eastward. In the winter falls of snow are frequent, and as almost every snow-storm is followed or accompanied by a gale of northerly or north-westerly wind, the snow is blown over the cliff and deposited in deep drifts at the cliff-foot on the ice, which is forced down by the weight.

As I have known a drift-bank of 20 or 30 feet formed by one gale of wind of as many hours' duration, it may be readily understood how in the course of a winter an accumulation of snow to the depth of several hundred feet may be formed, extending in a sloping direction to seaward thus:—



As soon as warm weather comes on in spring the surface snow is thawed; the water percolates downwards until it reaches the snow, which is colder than the freezing-point, and the whole is frozen into a solid mass of ice.

This process goes on to a greater or less extent according to the severity of the season, the quantity of snow, and the amount of windy weather, until the snow-formed ice attains great thickness and breaks off in large masses in the form of icebergs.

In Hudson's Bay the icebergs formed in this manner are small and scarcely deserving the name, but in the Straits they are large and lofty.

When passing through the Strait near to the north shore, I have seen some of these lying close to the cliff from which they had become detached, and showing projections and hollows corresponding to the form of the rocks from which they had broken away.

Whilst wintering at Repulse Bay on the Arctic circle in 1846–47 and 1853–54, I had an opportunity of observing the manner in which boulders are taken up and transported by ice.

In the early part of winter, when the sea-ice has attained considerable thickness, it adheres at low water to any stones it may rest upon, and as the tide flows, raises these from the ground. As the ice increases in thickness, these stones, some of them 3, 4, or 5 feet in diameter, are gradually imbedded in the ice, which attains a depth of 8 feet or more.

In the spring the surface-ice wastes away by the combined action of thaw and evaporation, whilst it is still acquiring fresh thickness underneath.

In the month of June, the boulders, which in the autumn were under the ice, now appear on its surface, and may be floated off to great distances, when the ice is broken up whilst still strong, by the action of winds and currents.

On the Aborigines of the Arctic and Sub-Arctic Regions of North America. *By* DR. RAE.

Remarks on some of the Races of India and High Asia (in connexion with Casts exhibited). *By* ROBERT VON SCHLAGINTWEIT.

Mr. Robert de Schlagintweit gave a short sketch of the aboriginal tribes of Central India, as also of the race inhabiting the country between the Karakorím and Sayan Shan, which go by the name of the Turks. He also presented, in illustration of his remarks, some metal casts* of native faces taken from life. The tribes composing the population of the mountain regions of Central India are the *Kols*, the *Gods*, the *Bils*, and the *Santals*.

In physical conformation these people differ most distinctly from either Hindoos or Mussulmans. In their religious observances also, and the habits of domestic life, they have nothing in common with their neighbours. The language originally spoken by them is now almost entirely lost, and it was only with great difficulty that we could collect from old people any remains of their former idiom.

Though there exist many affinities amongst the four tribes above mentioned, yet each preserves its peculiar and characteristic features. The complexion is remarkably dark, nearly approaching the colour of Negroes; the mouth is extremely large, though the lips, which are scarcely ever parallel to each other, are not very fleshy; the nose is broad and flat, and the hair, which is generally shaved off or cut very short, stands out stiff and straight. Though at first glance these tribes may show a superficial resemblance to the African race, yet a closer examination will disclose characteristic differences, especially with reference to the lower part of the head, which is more prominent and considerably stronger with the Negroes. By some ethnographers a remote affinity with Australian tribes has been pointed out; but the likeness, on closer comparison, proves merely an apparent one.

The mountainous countries inhabited by the Kols, Bils, and Santals are, for the greater part, covered with dense jungles, and at certain seasons of the year become so unhealthy as to prove extremely dangerous for every one except the natives themselves,—a most remarkable instance of the fact, that some human tribes are capable of living under conditions altogether fatal, or nearly so, to others.

Cultivation can only be carried on to a very limited extent; and the inhabitants chiefly occupy themselves in cutting down trees, and in hunting the wild animals with which their country abounds.

The clothing of this rude people is very scanty, consisting merely of a small piece of unbleached cloth for the loins, and another piece of the same wound round the temples, so as to leave a great part of the head exposed to the powerful rays of the sun. They have no shoes, but sometimes wear a kind of sandal made of rough wood, and shaped to the foot, with another small round covering of wood at its upper end, to afford a hold for the toes.

Their sole weapons are axes, in the use of which they display considerable expertness. For dwellings, they erect for themselves miserable huts constructed of bamboo and the leaves of various trees.

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* These casts are a selection from Messrs. de Schlagintweit's collection of 275 heads, published (1859) by T. A. Barkt at Leipzig.

The contempt with which they are universally treated by their neighbours, the Hindoos, has rendered them extremely shy and suspicious; whenever I approached one of their villages, they invariably left their huts and tried to conceal themselves in the dense jungles of the neighbourhood. Though I had the necessary supply of guides with me, yet their services in this respect were indispensable on many occasions.

M. de Schlagintweit passed on to the Turks, a people particularly recommending themselves to his notice, as presenting marked differences from all the tribes he had had occasion to observe.

This remarkable race inhabits those parts of Central Asia which to the north of Tibet are interposed between the Komakorínn, the Sayan Shan, and considerably to the east of it. In many respects they show points of resemblance to the Mongols, but nevertheless form a separate and distinct tribe, and may be considered as the original stock from which the Turks in Europe have sprung. Even at the present day the true Turkish language holds its ground amongst them; and though, on comparison with the kindred idiom used by the European Turks, there are many dialectic deviations to be observed, yet it is evident that the Turks in Central Asia have preserved the purity of the original tongue, whilst the related race in Europe have modified it with a considerable admixture of Persian and Arabic words.

Like their European brethren, the Asiatic Turks are fanatic Mussulmans, honest, active, and hospitable, and far more civilized than their neighbours the Tibetans. Their manners are characterized by the strictest observance of punctilious etiquette, some of the ceremonies being so complicated as to raise up an almost impassable barrier for all strangers.

The native dress is rather handsome and rich, varying according to the seasons. For winter, or when travelling over the mountains, the Turk wears a long fur coat, woollen trowsers, and a round fur cap. The stockings are of felt, and so long that they can be drawn over the trowsers, when they are fastened by an ornamental ribbon above the knee. So far, the dress, which we had to assume ourselves when disguised, is very convenient; but the shoes are so thin as to offer but a slight protection to the feet. The summer costume consists also of a coat and trowsers, a light cap for the head, and boots reaching up to the knee worn without any stockings.

Yárkand, their chief place, as also Káshgar, is one of the most important and flourishing places of Central Asia. The population is in general a wealthy one, and live in good solid houses.

The inhabitants of the mountainous parts are mostly shepherds; the principal occupation of those in the plains is trade, which they carry on with horses and Bactrian camels along routes apparently impracticable for loaded animals. The merchants travel as far south as Ladák and Pesháın, and to the north find their way to the shores of the Issikul lake. On the west they penetrate beyond the Russian frontier; but towards the east commercial intercourse is restricted by the large desert, stretching along the eastern part of the Kuenluen.

It may here be mentioned, that the caravan route from Yárkand to Ladák leads for more than fourteen days' march over uninhabited mountain country, at an elevation of from 14,000 to 16,000 feet. Passes above 18,000 feet in height occur; and the whole district is so bare and sterile, possessing so little vegetation, that the traders are obliged to carry with them even the food for their animals.

By far the greater part of the trade between India and High Asia, including the adjoining parts of Russia, is carried on by the Turks.

In conclusion we may remark that, besides our special geographical observations, we had occasion to collect various specimens of manufacture, mostly from Turkish and Tibeto-Indian parts; and we consider ourselves fortunate in being able to add more than 207 specimens to the splendid general collection now accumulated, under the energetic direction of Dr. Forbes Watson, within the walls of the India House Museum.

On the Tribes composing the Population of Morocco.

By Lieutenant EDWARD SCHLAGINTWEIT.

This paper was read by Mr. Hermann Schlagintweit, who stated that his brother Edward, First Lieutenant in the Bavarian Army, had joined the Spanish forces during their late campaign in Morocco. Subsequently he had made a second visit to Morocco in furtherance of certain scientific purposes of his own, when he received the most valuable assistance from the well-known British Resident in that country, Mr. James Drummond Hay*.

The principal population of Morocco, the Moors, are a mixed race, deriving their origin partly from the Berbers and partly from the Arabs. They form the most numerous section of the inhabitants of the towns. Their complexion is comparatively fair, not unlike that of the inhabitants of Southern Europe, while the colour of their hair is various, comprising both light and dark shades; the form of the face, as well as of the figure in general, betrays a tendency to stoutness. With regard to character, but little can be said in the way of praise. Like most Orientals, the Moors are false and covetous, grovelling in the lowest servility before their superiors, and full of arrogance and cruelty to those below them. This race took very little part in the late war, while the following ones showed themselves as possessing much greater energy, and capable, under proper guidance, of quitting themselves well in active service.

The various tribes of the *Berbers* or *Brabers* must be considered as the original inhabitants of this district. They were found already in possession of the country on the arrival of the Romans, as appears from the geographical terminology used by the latter in reference to these parts. The interesting work of "Al Hasem" of Granada—better known under his name, when a Christian, of "Leo Africanus,"—shows, moreover, that during their conquests in North-western Africa (650–700 A.D.) the Arabs were frequently engaged in conflict with these primitive tribes.

Like the Fellahs in Egypt who have succeeded in preserving the ethnographical type of the ancient inhabitants, so here also it occurs that, in spite of the many changes in the dynasties of the country, the pure type of the Berbers is still represented by a considerable proportion of the population. They chiefly inhabit Mount Atlas and its spurs, but have also extended themselves as far as Fez, Mekĭnéz, and the towns along the sea-coast.

In Morocco two principal tribes of the Berbers can be distinguished: the *Shlockhs*, who are settled in villages and towns; and the Amazirgens, forming a migratory and unsettled population.

The Kbílas (Kabiles) and the Shayvas in Algiers must also be considered as belonging to the Berber race. In person they are thin, but sinewy; their hair brown, occasionally reddish, and with those from the southern provinces rather dark. Though in general character not unlike the Moors, they are a much more active people, are good cultivators of the soil, and make hardy soldiers. One tribe in particular of the Berbers, the Hudnyas, have played an influential part at various times in the military history of Morocco. Like the Ianichars, they formed a strong and formidable guard, though often in opposition to the government; but were at last disbanded and scattered throughout various cantonments of the country.

The *Riffers* inhabit the mountain ranges along the Mediterranean, which begin at Tetuan and reach to Cape "Tres Forcas." Confined as they are to their almost inaccessible mountains, they form a distinct and well-marked race, their language even differing considerably from the Arabic. There are six principal tribes into which they are divided,—the Ghoniáras, Aksenáyas, Bukonē'a, Tems'manes, Gveláyas, and Kebdánas. They are almost entirely independent of the Emperor of Morocco, the small yearly tribute paid to him being offered rather to the head of their church than to their Emperor. The greater part of them are robbers and pirates; and, indeed, in the late war, when posted in the town of Tetuan for its defence, they exercised their native calling with a zeal and cruelty which considerably accelerated the surrender of the place.

The *Sūs* race. These tribes approach the Negro type in respect of complexion and general proportions, but their character is better than that of the preceding races. They are very active both in trade and agriculture, and evince great dexterity in the manufacture and use of arms. Their dependence upon the Emperor is of the same nature as that of the Riffers.

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* During his stay in the country Mr. Edward Schlagintweit took many facial and cranial casts, besides making numerous detailed measurements.

Geography of the North Atlantic Telegraph.

By Colonel TAL. P. SHAFFNER, *of the United States.*

The Route—Lands and Seas.—The route of the telegraph is from Scotland *viâ* Faröe Isles, Iceland, Greenland, and Labrador, to Quebec, there connecting with other lines to different parts of America.

The sea sections of the proposed telegraphic route are as well known to nautical geographers, excepting, perhaps, the places sounded by the Telegraphic Expedition last autumn (1859) between Labrador and Greenland, and between Greenland and Iceland. The bottoms of those seas were found to be deep mud, and a cable once laid thereon will lie undisturbed for all time. Icebergs float, and there is no part of the sea in which the cables will be laid where the bergs will reach the bottom. Arctic navigators, with whom the author has had the pleasure of conversing since his arrival from the voyage of last autumn, agree that if the cable can be carried into deep fiords on the respective coasts, there will be no danger of interruptions from icebergs. The author has seen such fiords on the coasts of Labrador and Greenland, and therefore regards the problem as solved.

The land sections are not of serious importance. A telegraph line can be constructed on land wherever the foot of man can be placed. Lines have been built over hills and valleys where neither waggon nor beast could go, and these regions were in the great Mississippi valley, a country having great variety of soil, surface, and climate.

Faröe Isles.—The cable will be landed at Thorshaven, the capital of the Faröe group, and from thence a few miles by land to Westerman's haven. The island is hilly, the roads inferior; there is but little cultivation; pasturage good; the people intellectual; religion Lutheran; it sends one member to the Danish Parliament; it has a governor, sheriffs, and other officers of state: the climate is about the same as Copenhagen, more mild than Stockholm, Quebec, Montreal, or Boston.

Iceland will be traversed by the line from Berufiord or Portland to Reikiavik. The people are highly educated, and a considerable trade is carried on between them and the Europeans. The French have some 120 vessels fishing on the south coast. They have free trade with foreign countries, and all the fisheries are free. The inhabitants are industrious and religious, and have their own local Parliament. The country is partially cultivated, but much of the island is covered with lava. The climate is moderate; the ice never interrupting navigation on the south and west coasts. There will be no difficulty whatever in running the telegraph across Iceland.

Labrador.—The cable will be landed in Hamilton Inlet, lat. 54° 30′ N. The line will then be run either to the Gulf or to the River St. Lawrence. This country is rolling or hilly, and covered with timber, principally pine, spruce, and juniper. The trees are large, many being 15 or 20 inches in diameter at the base. There is much grass where the country is open. Turnips, potatoes, and other vegetables are cultivated to a limited extent. The inhabitants are mostly Esquimaux. They are civilized, under the teachings of the Moravian missionaries. There is a station of the Hudson's Bay Company on Hamilton Inlet, about 50 miles from the sea. The coast is hilly and barren. Fishermen from Newfoundland are scattered along the coast, and many are employed in Hamilton Inlet. The cod and herring fisheries are the most profitable. The country is not much settled. There will be difficulties to be met in the construction of the line, and maintaining it across Labrador; but these difficulties will not be so great as those which have been overcome in other countries; for example, in Newfoundland, and the Southern and Western States of America. The line across Newfoundland traverses marshy and uninhabited regions, wholly unknown to the world until a few years ago, when it was explored for the telegraph.

Greenland.—The section of the route the least known is Greenland; and although that part of the country proposed to be traversed is not so cold as the climate of St. Petersburgh, a city of some 700,000 inhabitants, yet there prevails the most erroneous impressions in regard to the temperature of that interesting and wonderful country. Whether it is a continent, or numerous islands extending to the North Pole, is a problem yet to be solved. In the southern portion we find green valleys, covered with grass and vegetation, surrounded with mountains towering into the heavens; and these in the morning are covered with white glittering snow, which with the mid-day sun disappears, leaving exposed their blackened minarets and spires. The scenery is grand and picturesque.

The coasts of Greenland are barren hills and mountains. Along the shore are many islands. The fiords penetrate to the interior 10, 20, or 30 miles. Some of these bring out ice, others do not. Into one of the fiords which are free of ice will be carried the telegraph cable, as indicated in the map. The water is very deep, and no iceberg can reach the bottom, or go far up their meanderings to their heads. They do not freeze, except in narrow places, where there is still water. A cable can be easily laid from the sea into one of these fiords, and when brought to land it can be well secured against native ice, as is the case at many places in America, and on the belts and sound of the Baltic Sea.

The exact locality where the line is to cross Greenland has not been determined, but it will be in the southern portion, not 60 miles north of Cape Farewell. The particular kind of surface to be traversed—whether green valleys, or mountain ranges—is not fully known, but in either case no insuperable difficulties can be foreseen. What it is in the interior, or whether there be ice there or not, no one knows. Col. S. found alluvial soil on the ice several miles distant from the sea, and it may have been blown there from the interior. Some 12,000 deer are killed in the Holstenberg district every year. They disappear in winter. Whither do they go?

The ice travelled over by Colonel Shaffner was solid freshwater ice. The snow falls in small quantities. On the plateau some considerable collections of water were seen. There were many deep crevices. The thickness of the ice no one has been able to determine. The author does not believe it entirely rests upon the earth, but it forms bridges, and perhaps where he went it was 4000 feet above the level of the sea; or perhaps there was a cavern beneath, 1000 feet between the ice and the earth, exceeding in grandeur the great Mammoth Cave of America, with its 200 subterranean avenues. This may seem most wonderful, but he had many reasons for believing that it was possible. He had been in some of the caverns, and heard a waterfall resembling the rushing of a river over rocks. The bergs from the fiord blinks, he noticed were clear and clean ice; no gravel or earth either in or on them, excepting those that were near the shore. If the ice were upon the earth in the interior, we might expect to find some earth in the bergs. He has seen boulders on bergs, but they came from the glaciers of the north, or from the sides of the blinks crushing against the mountains as the ice moved from the interior. The inhabitants are Danes and Esquimaux. The Julianahaab District is the most southern in Greenland, and has about 2600 Esquimaux. They are all civilized, and mostly members of the Lutheran Church. There are a few Moravians. The children are baptized, and at fourteen years old confirmed. They have churches and schools, and they preach, sing, and pray. In the principal churches they have organs and some fine paintings.

The town of Julianahaab has about 300 inhabitants. The people received the visit of the party last autumn with much joy. The houses were stone and frame, and covered with slate. It is not cold enough for double windows. They had cows and sheep. The Esquimaux lived in stone huts covered with earth, fully as comfortable as many log cabins that Colonel Shaffner has lived in when in the western forests of America.

The Esquimaux are honest and good-hearted. They never steal unless on the verge of starvation. The men treat their wives well. The children are never whipped. Peace, love, and domestic happiness seem to be more common to them than to the more civilized races. It will not be difficult to have a telegraph line maintained in Greenland, with the aid of such people; and, in fact, a telegraph line can be constructed across the hills, the valleys, and the fiords of Greenland, and it can be maintained thereafter with much more facility and certainty than has been done across the plains of Russia, the mountains of Norway, the swamps of Newfoundland, the inundated lands of the Mississippi, the uninhabited forests of America, or the Alpine ranges of Europe.

On the Lost Polar Expedition and Possible Recovery of its Scientific Documents. By Captain PARKER SNOW.

Captain Parker Snow, in addressing the audience upon the subject of his paper, stated that the great object he had in view was to keep before the public the fact that we had not yet done all that might be done as regarded the lost polar expedition. Those who went out in that expedition ought, none of them, ever to be forgotten; and it was our duty to persevere in ascertaining their real fate until positive evidence came forward concerning it. This evidence, he asserted, had not yet been found; and he was prepared to show that more could be obtained if right measures were taken.

He then commenced his arguments by giving an analysis of Franklin's instructions, and pointed out how certainly numerous scientific observations of great value must have been made by the officers in that expedition. He enumerated the different searching expeditions, and with much pleasure dwelt upon the exertions made by the several leaders and subordinates engaged upon this work, many of whom he named. He next pointed out Dr. Rae's discoveries, and then those of the 'Fox' under the present Sir Leopold M'Clintock, doing full justice to one and all. After this, he dissected the whole information that had been obtained by making the following remarks:—

"First of all," said he, "what do we know for a *certainty* concerning the lost expedition? Why this: 105 persons landed at Point Victory in April 1848, and Captain Crozier (one of their chiefs) said that *he* or they, or some of them, were going to start on the 26th for Back's Fish River. They do not say a word about being in want of assistance, nor yet that they are suffering. They have abandoned their ships and are going southward, even as Captain M'Clure had intended to do with a part of his crew.

"This is all we positively know from any written evidence. What else we know is from other testimony. It is as follows:—Three skeletons—perhaps belonging to the 105, perhaps not—have been found; also a boat. Forty of our countrymen were seen by the natives in the spring of 1850 walking to the Fish River, where, later in the year, it is said that some of them died. Traces of others have been found part of the way up the Fish River, and along the Boothian Isthmus, the coasts of Boothia, and King William Island. Rumours of white men, going westward along the coast of America, have been heard for several years past. To Cape Warren, the Peel River, the Fish River, and, about the Melville Peninsula, strange tales attach great interest. These places have yet to be searched, and the mystery connected with them examined.

"Such is what we know. Now what is it we suppose? Briefly this:—From April 1848 to the spring of 1850 is two years. Clearly the party must have been wandering about during that interval. What so likely as that, in the summer of 1848, they found open water for their boats, and went away to the westward (or at all events one party did), and tried to reach the Mackenzie or Peel River. Some may have perished, some have gone another way than by the coast (possibly by a direct channel yet undiscovered by us), and finally, being unsuccessful in their western route, they return to the eastward for Fish River, and perhaps a few of them towards Lancaster Sound, or the channels leading into Baffin Bay; in fact, to any place, where a hope of relief, and where good hunting would be presented.

"This hypothesis would explain away the lapse of time, and account for only *forty* being seen by the natives in 1850. It is further strengthened by other circumstances founded on negative facts.

"They did not take away any of the Fury Beach stores, though well known to them as existing at only about 200 miles' distance: they did not send information of distress through the Esquimaux or Indians, as we now know could have been done, even as Captain Collinson and Captain Maguire sent notices of relief: they did not say a word about being starving or in want of immediate aid; and many other things they did not do, which we should expect would have been done, in case of great distress. Hence we may infer that in April 1848 they were not so badly off as is supposed. Had they been so, why did they not visit the Fury Beach stores and get relief? Those stores are even now in excellent order, as may be known from Captain M'Clintock's published Journal. Yet we find them unused, at all events for any large supply, though it is possible they may have been visited by a few of the lost party.

"Remarks have been made about the Franklin Expedition suffering from Goldner's provisions. But, independent of all other argument on this point, there is one fact to be got over, before we can agree to such an idea;—the ships wintered at the threshold of their explorations, yet afterwards *went onward into unknown regions* instead of returning, as wisdom would have dictated, on finding their stores defective!

"Another fact to be well considered is, that close attention to all the information obtained from the natives, leads to a belief that the actual ground where the whole truth could be known has not yet been examined. The natives told Captain M'Clintock that the white people had gone to a place where there was *plenty of salmon*. Now we know the lakes of South Boothia abound in salmon.

"Again, the Esquimaux referred to parts known by certain names; as, for instance, *Amitoke, Neitchillee*, and *Akkollee*. These parts, however, were not visited by our late explorers, perhaps from not knowing where they were. But a careful reading of the various Arctic Voyages of Parry, Ross, Simpson, and Back, would have shown that the places named, all exist about the Boothian Isthmus southward; and it is there, and in adjoining localities, we find all the plate and other articles in possession of the natives.

"More argument could be brought forward; but it is enough to call attention to one other important fact, viz. that Ross and his small crew, after being frozen in for three years, managed to escape from a position almost identical with that of Franklin's ships, and then get home by way of Lancaster Sound.

"That we have no traces of the Franklin crews attempting the same thing is very singular. We must therefore infer either that they were not in absolute distress, or else that one party did visit Fury Beach without being able to leave a notice. Be it as it may, assuredly the Expedition would never have abandoned their journals and other documents, without first placing them in some sort of security. When Ross escaped he carried even minerals with him! These with other things he had to abandon; but he deposited them in a secure place, and they were afterwards brought home to England in a whaling ship sent expressly to the locality for them. Can we suppose that the officers and crew of a national expedition like Franklin's—and withal a scientific one—would not take equal care to preserve the records of their labours? The question needs no answer. There can be little doubt about it in the minds of all impartial persons; and it only requires a good summer search to know the truth."

Captain Snow then brought forward evidence to show that life could be prolonged in the arctic regions, and that the place was not so destitute as generally supposed. Sir R. Murchison himself had given good reasons in support of this view; and Lord Wrottesley, Baron von Humboldt, Sir Francis Beaufort and others had expressed something similar. The burial of the dead, too, was another thing not to be forgotten. Three sailors were buried suitably on shore, therefore it is almost certain Sir John Franklin would have been interred in like manner; and as the Esquimaux are very superstitious concerning the dead, it is possible important records can be found near the locality where the illustrious chief is known to have died.

Other arguments were brought forward by Captain Snow, who stated that he had a committee formed of well-known names to aid him in a renewed search he was prepared to make in a small vessel of from 75 to 100 tons if sufficient means could be raised. A brave American (Mr. Hall) was already on his way there to try and do the work; and it was for our credit and honour that another attempt should be made by our own flag to complete that which comparatively could now be easily done.

On the Proposed Communication between the Atlantic and Pacific, viâ *British North America. By* Captain M. H. SYNGE, *R.E.*

On the Geographical Distribution of Plants in Asia Minor. By PIERRE DE TCHIHATCHEF.

On the Excavations on the Site of the Roman City of Uriconium at Wroxeter. By THOMAS WRIGHT, *F.S.A.*

STATISTICAL SCIENCE.

Opening Address by NASSAU W. SENIOR, *M.A., President of the Section.*

IN 1856 the General Committee of the British Association decided that the Section over which I have the honour to preside should be entitled "The Section of Economic Science and Statistics."

I have looked through the papers which since that time have been communicated to us, and I have been struck by the unscientific character of many of them.

I use that word not dyslogistically but merely distinctivingly, merely as expressing that the writers had wandered from the domain of science into that of art.

I need scarcely remind you that a Science is a statement of existing facts, an Art a statement of the means by which future facts may be brought about or influenced. A Science deals in premises, an Art in conclusions. A Science aims only at supplying materials for the memory and the judgment. It does not presuppose any purpose beyond the acquisition of knowledge. An Art is intended to influence the will: it presupposes some object to be attained, and it points out the easiest, the safest, or the most effectual conduct for that purpose.

The subjects to which the British Association has directed our attention are Economic Science, and Statistics.

Economic Science, or, to use a more familiar name, "The Science of Political Economy," may be defined as "The Science which states the laws regulating the production and distribution of wealth, so far as they depend on the action of the human mind."

I say, "so far as they depend on the action of the human mind," in order to mark to which of the two great genera of sciences, the Material, or, as they are usually called, the Physical, and the Mental, or, as they are frequently called, the Moral, sciences, Political Economy belongs.

Unquestionably the political economist has much to do with matter. The phenomena attending the production of material wealth occupy a great part of his attention; and these depend mainly on the laws of matter. The efficacy of machinery, the diminishing productiveness, under certain circumstances, of successive applications of capital to land, and the fecundity and longevity of the human species, are all important premises in political economy, and are all laws of matter. But the political economist dwells on them only with reference to the mental phenomena which they serve to explain; he considers them as among the motives to the accumulation of capital, as among the sources of rent, as among the regulators of profit, and as among the causes which promote or retard the pressure of population on subsistence.

If the main subject of his studies were the physical phenomena attending the production of wealth, a system of political economy must contain a treatise on mechanics, on navigation, on agriculture, on chemistry—in fact, on the subjects of almost all the physical sciences and arts, for there are few of those arts or sciences which are not subservient to wealth. All these details, however, the political economist avoids, or uses a few of them sparingly for the purpose of illustration. He does not attempt to state the mechanical and chemical laws which enable the steam-engine to perform its miracles—he passes them by as laws of matter; but he explains, as fully as his knowledge will allow, the motives which induce the mechanist to erect the steam-engine, and the labourer to work it. And these are laws of mind. He leaves to the geologist to explain the laws of matter which occasion the formation of coal, to the chemist to distinguish its component elements, to the engineer to state the means by which it is extracted, and to the teachers of many hundred different arts to point out the uses to which it may be applied. What he reserves to himself is, to explain the laws of mind under which the owner of the soil allows his pastures to be laid waste, and the minerals which they cover to be abstracted; under which the capitalist employs, in sinking shafts and piercing galleries, funds which might be devoted to his own immediate enjoyment; under which the miner encounters the toils and the dangers of his hazardous and laborious occupation; and the laws, also laws of mind, which decide in what proportions the produce, or the value of the produce, is divided between the three classes by whose concurrence it has been obtained.

When he uses as his premises, as he often must do, facts supplied by physical science, he does not attempt to account for them; he is satisfied with stating their existence. If he has to prove it, he looks for his proofs, so far as he can, in the human mind. Thus the economist need not explain why it is that labour cannot be applied to a given extent of land to an indefinite amount with a proportionate return. He has done enough when he has proved that such is the fact; and he proves this by showing, on the principles of human nature, that, if it were otherwise, no land except that which is most fertile, and best situated, would be cultivated. All the technical terms, therefore, of political economy, represent either purely mental ideas, such as *demand, utility, value,* and *abstinence,* or objects which, though some of them may be material, are considered by the political economist so far only as they are the results or the causes of certain affections of the human mind, such as *wealth, capital, rent, wages,* and *profits.*

The subject matter of political economy is, I repeat, wealth. The political economist, as such, has nothing to do with any of the other physical or moral sciences, or with any of the physical or moral arts, excepting so far as they affect the production or distribution of wealth. Whether wealth be a good or an evil, whether it be conducive to human morality or to human happiness, that it be hoarded or that it be consumed, that it be accumulated in masses, or that it be generally diffused, are questions beyond his science. His business is to state what are the effects on the production and distribution of wealth, or, to use a shorter expression, the economic effects, of accumulation and of expenditure, of the different kinds of consumption, and of the aggregation in a few hands, or the division among many, of the things of which wealth consists. Whenever he gives a *precept,* whenever he advises his reader to do any thing, or to abstain from doing anything, he wanders from science into art, generally into the art of morality, or the art of government.

The science of statistics is far wider as to its subject matter. It applies to all phenomena which can be counted and recorded. It deals equally with matter and with mind. Perhaps the most remarkable results of the statistician's labours are those which show that the human will obeys laws nearly as certain as those which regulate matter.

There are countries in which we find year after year the same number of marriages at the same ages and in the same proportion to the population, the same number of children to a marriage, the same number of bankruptcies, and the same number of crimes and suicides, committed at the same ages, and by each sex in permanent proportions; in which the average height, the average weight, the average consumption and production of commodities, and the average longevity, of men and of women, continue for long periods unaltered.

There are others in which the number or the proportion of these events varies; in which marriages, births, deaths, crimes, consumption and production, and even the average stature are different at different periods. This uniformity, or these differences, are detected by the statistician. His task is over when he has stated and recorded them. It is the business of the legislator to draw from the figures of the statistician, practical inferences. To ascertain the circumstances, moral, commercial, or political, under which the tribute paid by his countrymen to insolvency, crime, sickness and death, has been increased, has been diminished, or has remained stationary—these circumstances will often appear to be under control, and by watching the statistical results of every attempt to control them, he will ascertain whether they *are* under control or not.

We have been told that a statesman "reads his history in a nation's eyes." I should rather say that he reads it in a nation's figures.

But it is not only to the statesman that statistics are useful, many of the most important and most useful employments of capital depend on them. Vital statistics are the base of life insurance. They decide the value of annuities, of life estates, and of reversions. Every man in the management of his property has to consult them. The statistics of fires regulate fire insurance, those of wrecks regulate marine insurance. Wherever the success or failure of an undertaking depends on the calculation of chances, and wherever the events subject to those chances have been observed and recorded in numbers sufficient to afford an average, the prudence or imprudence of the undertaking depends on that average. To *give* that average is the business of the statistician. To *act* on it is the business of the speculator. If in London one house in two thousand were burnt down every year, nothing would be gained or lost by insuring houses in London at a shilling per cent. per annum. If one in a thousand were burnt down, such insurance would be ruinous. If only one in three thousand, it would be very profitable. But, I repeat that the observation, the recording and the arranging facts, which is the science of statistics, and the ascertaining, from observation and from consciousness, the general laws which regulate men's actions with respect to production and exchange, which is the science of political economy, are distinct from the arts to which those sciences are subservient. We cease to be scientific as soon as we advise or dissuade, or even approve or censure.

I said, that I had been led into this train of thought by looking through the papers which have been communicated to this Section since 1856. I find that we received during that year "Suggestions on the education of the people."

We had a paper, "On the general principles by which Reformatory Schools ought to be regulated." We had another, "On the importance of open and public Competitive Examinations."

In 1857 we had one on the prevention of crime; one on the reasons for extending limited liability to joint-stock banks; and one on the apprenticeship system in respect to freedom of labour.

In 1858 we had one on the principle of open competition; one on public service, academic and teacher's examinations; one on the importance of a colonial penny postage to the advancement of science and civilization; and one on the race and language of the gypsies.

If it be said that in all these papers, except indeed the very last, there was a reference to statistical facts, or to economic principles, and that therefore they were properly communicated to this Section, the answer is, that there is no province of the great arts of legislation, of administration, of commerce, of war, indeed, of any of the arts which deal with human feelings, in which frequent reference must not be made to political economy, and occasional reference to statistics. There is scarcely a moral art therefore of which we should not be able to take cognizance.

But I do not think that such an extension of our jurisdiction would be advisable. I believe that in mental, as in manual arts, the division of labour is useful. Within the strict limits of economic science and statistics a large field is open to us. It appears to me that we shall do well, if, as far as may be practicable, without much inconvenience, we confine ourselves within it, and deviate as little as we can into the numerous arts to which those sciences afford principles.

On the True Principles of an Income Tax.
By the Rev. J. Booth, *LL.D., F.R.S.*

On Educational Help from the Government Grant to the destitute and neglected children of Great Britain. By Mary Carpenter.

The educational movement, as such, is of comparatively recent date in our country. The importance of popular education was not generally acknowledged in England fifty years ago: but yet as early as in the sixteenth century there were distinct efforts made to give instruction to the *very poorest*, as is proved by the King Edward and many other endowed Charity Schools. These gradually became employed by a higher class than the children for whom they were originally intended, and a part of the population were uncared for. In 1781 Raikes began the first Sunday school for outcast children; in 1800 Bell and Lancaster began day schools, to give *gratuitous instruction* to the *very lowest*. *Now* the Sunday schools no longer receive the vagrant children, and the Bell and Lancaster schools have gradually merged into the National and British pay schools. A large class of the people are instructed by these schools, but those who most need instruction are not able to attend them.

At the Educational Conference in 1857, H.R.H. Prince Albert stated that there are 2,200,000 children in England and Wales not at school, whose absence cannot be traced to any legitimate cause. If Government educational help is given to any portion of the population, it ought, for the good of society, to be directed efficiently towards these. From this uneducated mass spring the *pauperism* and *crime* which are so great a national burden. Union Inspectors find the state of degraded ignorance in which children usually come to the workhouse indicative of the existence of a large portion of the population *untouched by existing institutions*; in Liverpool, out of 19,336 persons apprehended in 9 months, only 3 per cent. could read and write. *Industrial* and *Ragged Schools* alone have attempted distinctly to act on this class. Wherever they have been *well conducted* and *efficiently supported* they have completely effected the object intended, but many have failed from want of teaching power. The children of this class, in addition to ordinary instruction, must have much moral and industrial training, and schools capable of acting on them must be adapted to their wants, and of a very different character from the ordinary pay schools.

The Committee of Council on Education, in administering the Parliamentary Grant, have adapted their regulations to the pay schools; in 1859, 6222 Certificated Teachers for them were partially paid, receiving £86,328; Assistants, £6244; Pupil Teachers, £252,550; thus providing a good teaching power for 9555 schools. No teaching power (except a gratuity to certified masters, who very seldom are qualified for such schools) *and no educational help* is allowed to the schools for the destitute and neglected children.

The importance of giving an efficient teaching power to the lowest and most ignorant children was acknowledged by Parliament in 1849, when an annual grant of £30,000 was made to teachers in union schools, with a much lower test than that required for certificated masters. The Parliamentary Committee of Inquiry, in 1853, into the Condition of Criminal and Destitute Juveniles, reported the "beneficial effects produced on the most destitute classes" by the Ragged and Industrial schools, and their *need of help* from the Educational Grant; that aid is still required, to carry out efficient action on the destitute and neglected children of Great Britain.

On the Economical Results of Military Drill in Popular Schools.
By EDWIN CHADWICK, *Esq., C.B.*

On the Physiological as well as Psychological Limits to Mental Labour.
By EDWIN CHADWICK, *Esq., C.B.*

The business of education still requires for its successful prosecution, scientific observation, and the study of the subject to be operated upon—the human mind. Even to empirical observation, it should have suggested itself that the mind has conditions of growth which are required to be carefully noted, to adapt the amount of instruction intended to be given to the power of receiving it. It is a psychological law that the capacity of attention grows with the body, and that at all stages of bodily growth the capacity is increased by the skilful teacher's cultivation. Very young children can only receive lessons of one or two minutes' length. With increasing growth and cultivation, their capacity of attention is increased to five minutes; then to ten, and at from five to seven years of age, to fifteen minutes. With growth and cultivation, by the tenth year a bright voluntary attention may be got to a lesson of twenty minutes; at about twelve years of age to twenty-five minutes; and from thence to fifteen years of age, about half an hour: that is to say, of lessons requiring mental effort, as arithmetic, not carried beyond the point at which the mind is fatigued, with the average of children and with good teaching. By very skilful teachers and with very interesting lessons, the attention may be sustained for longer periods; but it is declared by observers that prolonged attention beyond average limits is generally at the expense of succeeding lessons.

The preponderant testimony which I have received in the course of some inquiries into educational subjects, is that with children of about the average age of ten, or eleven, or a little more, the capacity of bright voluntary attention, which is the only profitable attention, is exhausted by four varied lessons to subjects and exercises requiring mental effort of half an hour each in the forenoon, even with intervals of relief. After the mid-day meal the capacity of voluntary attention is generally reduced by one-half, and not more than two half-hour lessons requiring mental effort can be given with profit.

The capacity of attention is found to be greater in cold weather than in hot, in winter than in summer.

I collect that the good ventilation, lighting, and warming of a school-room will augment the capacity of attention of the pupils by at least one-fifth, as compared with that of the children taught in school-rooms of the common construction.

I also collect, that the capacity of attention varies with bodily strength and weakness. It is reported to me that school-boys, of nearly the same ages and conditions, of the same school-rooms, and under the same tuition, being weighed, and divided into two classes, the light and the heavy, the attainments, as denoted by the number of marks obtained, were found to be the greatest with the heaviest, that is to say, those of the greatest health and bodily strength.

These were chiefly of town-born children, of common habits. The robust children of rural districts, of less cultivated habits of attention, are found to be slower in receiving ideas; but with cultivation they are brought up to equal capacities of attention, and to greater retentiveness of the matter taught, than the common classes of town-born children.

There are differences in the capacities of attention in different races, or in the habits of attention created previously to the school-period by parents of different races. The teacher of a large school in Lancashire, who had acted as a school-teacher in the southern counties, rated the capacity of attention of the native Lancashire children as 5 to 4, as compared with those in Norfolk. In other instances the differences were wider.

Experienced teachers have testified to me that they can and do exhaust the capacity of attention, to lessons requiring mental effort, of the great average of children attending the primary schools in England, in less than three hours of daily book instruction, namely, two hours in the morning, and one hour after the mid-day meal.

Infants are kept in school, and the teacher is occupied in amusing and instructing them, for five or six hours, but the duration of mental effort in the aggregate bears only a short proportion to the whole time during which they are kept together. So in schools for children of more advanced ages. Even the smaller amount of mental effort in infant schools is, however, subject to dangerous excess. I am assured by a teacher in the first infant school established in Scotland, that he did not know a pre-eminently sharp child who had in after life been mentally distinguished.

In common schools, on the small scale, the children will frequently be not more than one-half the time under actual tuition; and in schools deemed good, often one-third of their time is wasted in changes of lessons, writing, and operations which do not exercise, but rather impair the receptive faculty.

It may be stated generally that the psychological limit of the capacity of attention and of profitable mental labour is about one-half the common school-time of children, and that beyond that limit instruction is profitless.

This I establish in this way. Under the Factories Act, whilst much of the instruction is of an inferior character and effect, from the frustration of the provisions of the original bill, there are now numerous voluntary schools, in which the instruction is efficient. The limit of the time of instruction required by the statute in these half-time schools for factory children is three hours of daily school teaching, the common average being six in summer and five in winter. There are also pauper district industrial schools, where the same hours, three daily, or eighteen in the week, or the half-time instruction, are prescribed; which regulation is in some instances carried out on alternate days of school teaching and on alternate days of industrial occupation. Throughout the country there are now mixed schools, where the girls are employed a part of the day in needlework, and part of the day in book instruction. Now I have received the testimony of school inspectors and of school teachers, that the girls fully equal in book attainments the boys who are occupied during the whole day in book instruction. The preponderant testimony is that in the same schools, where the half-time factory pupils are instructed with the full-time day scholars, the book attainments of the half-time scholars are fully equal to those of the full-time scholars, *i. e.* the three hours' are as productive as the six hours' mental labour daily. The like results are obtained in the district pauper schools. In one large establishment, containing about six hundred children, half girls and half boys, the means of industrial occupation were gained for the girls before any were obtained for the boys. The girls were therefore put upon half-time tuition, that is to say, their time of book instruction was reduced from thirty-six hours to eighteen hours per week, given on the three alternate days of their industrial occupation, the boys remaining at full school-time of thirty-six per week —the teaching being the same, on the same system and by the same teachers, the same school attendance in weeks and years, in both cases. On the periodical examination of the school, surprise was expressed by the inspectors at finding how much more alert mentally the girls were than the boys, and in advance in book attainments. Subsequently industrial occupation was found for the boys, when their time of book instruction was reduced from thirty-six hours a week to eighteen; and after a while the boys were proved upon examination to have obtained their previous relative position, which was in advance of the girls. The chief circumstances to effect this result, as respects the boys, were the introduction of active bodily exercises, the naval and the military drill, and the reduction of the duration of the school teaching to within what appear to me to be the psychological limits of the capacity of voluntary attention.

When book instruction is given under circumstances combining bodily with mental exercises, not only are the book attainments of the half-time scholars proved to be more than equal to those of the full-time scholars, but their aptitudes for applying them are superior, and they are preferred by employers for their superior alertness and efficiency.

In the common course of book instruction, and in the average of small but well-managed long-time schools, children after leaving an infant school are occupied on the average six years in learning to read and write and spell fairly, and in acquiring proficiency in arithmetic up to decimal fractions. In the larger half-time schools, with a subdivision of educational labour, the same elementary branches of instruction are taught better in three years, and at about half the annual expense for superior educational power.

The general results stated, I have collected from the experience during a period of from twelve to fifteen years of schools, comprising altogether between ten and twelve thousand pupils. From such experience it appears that the general average school-time is in excess full double of the *psychological* limits of the capacities of the average of children for lessons requiring mental effort.

I have not hitherto been enabled to carry my inquiries to any sufficient extent for a statement of particular results, to the schools for children or youth of the higher ages, but I believe it will be found that the school and collegiate requirements are everywhere more or less in excess of psychological limits. I gather that the average study, continuous and mental labour, of successful prizemen at the universities is from five hours and a half to little more than six hours of close mental labour or exertion from day to day. An able Oxford examiner informs me, that if he ever hears that some one is coming up for examination who has been reading twelve or thirteen hours a day, he is accustomed to exclaim, "that man will be plucked!" and during his experience of thirteen years as an examiner at Oxford, he has never known an instance to the contrary. In respect to the mental labour of adults, it is observed by Sir Benjamin Brodie in his 'Psychological Inquiries,'— "A man in a profession may be engaged in professional matters for twelve or thirteen hours daily, and suffer no very great inconvenience beyond that which may be traced to bodily fatigue. The greater part of what he has to do (at least it is so after a certain amount of experience) is nearly the same as that which he has done many times before, and becomes almost matter of course. He uses not only his previous knowledge of facts, or his simple experience, but his previous thoughts, and the conclusions at which he had arrived formerly; and it is only at intervals that he is called upon to make any considerable mental exertion. But at every step in the composition of his philosophical works Lord Bacon had to think, and no one can be engaged in that which requires a sustained effort of thought for more than a very limited portion of the twenty-four hours, &c.

"But great things are accomplished more frequently by moderate efforts persevered in with intervals of relaxation during a very long period. I have been informed that Cuvier was usually engaged for seven hours daily in his scientific researches; but these were not of a nature to require continuous thought. Sir Walter Scott, if my recollection be accurate, describes himself as having devoted about six hours daily to literary composition, and his mind was then in a state to enjoy some lighter pursuits afterwards. After his misfortunes, however, he allowed himself no relaxation, and there can be little doubt that this over-exertion contributed as much as the moral suffering which he endured to the production of the disease of the brain, which ultimately caused his death. Sir David Wilkie found that he was exhausted, if employed in his peculiar line of art for more than four or five hours daily; and it is probable that it was to relieve himself from the effects of too great labour that he turned to the easier occupation of portrait-painting. In fact, even among the higher grades of mind there are but a few that are capable of sustained thought, repeated day after day, for a much longer period than this."—P. 9-13.

Sir Benjamin Brodie has stated to me that he subsequently ascertained that in the above passage he had rather exceeded the limits of the mental labour of Sir Walter Scott, who, in a conversation on the topic, in the presence of Sir Charles Lyell and Mr. Lockhart, had declared that he worked for three hours with pleasure, but that beyond about four hours he worked with pain. Sir Benjamin states to me that he is of opinion "that for young children three or four hours' occupation in school must be even more than sufficient, and that they will be found in the end to have made greater progress, if their exertions are thus limited, than if they are continued for a longer period."

In large public establishments in which I have had an executive direction, I have not found it practicable to sustain, on the average, for longer than six hours per diem, from day to day, continuous and steady mental labour on the part of adults.

I find ground for the belief that as more and more of mental effort and skill is required in the exercise of the manual arts, the hours of work must be more and more reduced for the attainment of the best economical results without waste of the bodily power.

The psychological limits to mental labour are governed by *physiological* limits, which in the case of young children are first indicated by bodily pain experienced, in continued sedentary constraint, from suppressed muscular activity, or from muscular irritability. As respects children, the physiological case is put in the following letter which I wrote to Professor Owen, and in his answer:—

"Dear Owen,—Permit me to submit to you for your consideration and for my instruction, some questions on topics of observation made from time to time officially on the common practice of popular education, whether, in the duration of sedentary attention which its theory requires, it is not at variance with elementary principles of physiology?

"First, let me observe upon the very young of our species, their mobility at the periods of growth, particularly in infancy,—their constant changes of bodily position, when free to change,—their incessant desire for muscular exertion,—their changes, short at first, longer as growth advances,—these changes being excited by quickly varying objects of mental attention, and forming incessantly varying alternations of exertion and repose, with manifestations of pleasure when allowed free scope for them, of pain when long restrained. Now to what physiological conditions do these alternations of exertion and repose subserve?

"When obstructed and subjected to constraints for long periods, and when pain and mental irritation and resistance are excited amongst *classes*, are not the pain and resistance to be taken as a remonstrance of nature against a violation of its laws?

"The theory of the common practice of school instruction is of five and as much as six hours' quietude, and for intervals of three hours each, perfect muscular inactivity and stillness of very young and growing children from seven to ten years old, and during this constrained muscular inactivity, continuous mental attention and labour.

"To ensure these conditions of continued bodily inactivity and prolonged mental labour, the common office of the schoolmaster is everywhere a war for the repression of resistances and incipient rebellions. But are not these resistances excited by nature itself? Are not desk cutting, whittling with knives, mischief, conditions of irritability, manifestations of excessive constraints against physiology? If the condition of muscular inactivity were completely enforced, what does physiology tell us may be expected from these restraints? I might ask you, indeed, whether much of the insanitary conditions of our juvenile and very young populations are not consequences following from them?

"First, there is the proverbial pale-facedness of the young scholar, and a lower bodily condition of those who are subject to the confinement of schools, even of the best construction and ventilation, than of those who are free from them and at large, at liberty to follow natural instincts.

"When the weakly fail in health in a marked degree under the restraints of the school, the remedy is restoration to natural freedom, which commonly leads to improved health. I cannot but attribute to the lowering of the system and bodily debility produced by this excessive school constraint (even where there is good ventilation), and the consequent exposure to epidemic conditions and other passing causes of disease, a large share of our juvenile mortality, especially between seven and ten years of age, when the opportunities of retrieving the effects of the school constraints by athletic exercises are less than at later periods.

"But the constraints of a school are accomplished most fully in girls' schools, more especially in boarding schools, where the sedentary application of young children is extended to eight hours daily, and diseases are attendant upon them, which I cannot help ascribing largely to violations of the laws of physiology. In Manchester, with the increase of prosperity, an increased proportion of females have been sent to boarding schools and high class schools with long hours; and I am assured by Mr. Roberton, who is especially conversant with the diseases of females, that the proportion of the mothers of the middle class who cannot suckle their own children is increasing. He has shown me statistically that, with all the care bestowed upon females who have been so highly educated, the failures and deaths in childbirth are full sevenfold greater than amongst females of a lower condition in life, who have had less school restraint and sedentary application, and more freedom and muscular development in childhood. Cases of spinal distortion, nervous disorder, nervous mania, and hysteria, prevail peculiarly amongst the middle and higher class of females, whose education has been of prolonged sedentary occupation, even under the best sanitary conditions in other respects. As applied to them, it is a proverbial observation that 'ailing mothers make moaning children.' A lady who was eminent as a boarding-school teacher, but who has retired from business, has observed painful evidence of the injury done by the prolonged hours of sedentary application which custom and the demands of parents require, and she confirms the experience of the best half-time schools, that better instruction might be given in shorter hours. I have received a body of evidence from able teachers, that they can and do exhaust the capacity of attention to book instruction in half the time for which sustained attention to such instruction and bodily inactivity is demanded by custom.

"But what I seek is the sanction of your opinion, as to whether, if the laws of physiology be duly consulted for providing a sound body for a sound mind, other treatment is needed than that which prevails in schools, of requiring five or six hours of sedentary occupation for children in the infantile stage, and seven or eight for those in the juvenile stage? I appeal to you more particularly from the fact, that in lectures and papers the teaching of physiology is insisted upon as an additional element of popular education, and an additional demand of time in those schools, the whole condition and theory and attempted practice of which, though not yet so recognized generally by professors of the science, appears to me to be a large violation of it, and an offence against infantile nature.

"Yours ever, &c."

"My dear Chadwick,—I have perused and carefully considered every point in the inquiry which you have addressed to me, and I concur completely with your belief in the agreement with nature of the changes you recommend in the distribution and change of the periods devoted to school restraint and studies, and to bodily exercise and relaxation.

"All the nutritive functions and actions of growth proceed more vigorously and rapidly in childhood and youth than in mature life,—not merely as regards the solids and ordinary fluids, but also in the production of those imponderable and interchangeable forces which have sometimes been personified as 'nervous fluid,' 'muscular force,' &c. Using the latter term to exemplify my meaning, the excess of nervous force is in the child most naturally and healthily reduced by its conversion into muscular force; and at very short intervals, during the active or waking period of life, the child instinctively uses its muscles, and relieves the brain and nerves of their accumulated force, which passes, by the intermediate contraction of the muscular fibre, into ordinary force or motion, exemplified by the child's own movements, and by those of some object or other which has attracted its attention.

"The tissues of the growing organs, brain, muscles, &c., are at this period of life too soft to bear a long continuance of their proper actions; their fibres have not attained their mature tone and firmness; this is more especially the case with the brain-fibre. The direct action of the brain, as in the mental application to learning, soon tires; if it be too long continued, the tissues are unhealthily affected; the due progress of growth, which should have resulted in a fibre fit for good and continuous labour at maturity, is interfered with; the child, as an intellectual instrument, is to that extent spoiled by an error in the process by which that instrument was sought to be improved.

"The same effect on the muscular system is exemplified in the racers that are now trained to run, at 2½ or 3 years' old, for the grand prizes at Doncaster or Epsom. The winner of the 'Derby' never becomes an 'Eclipse' or 'Flying Childers,' because the muscular system has been overwrought two or three years before it could have arrived at its full development, which development is stopped by the premature over-exertion.

"If the brain be not stimulated to work, but is allowed to rest; and if, at the same time, the muscles be forbidden to act, there then arises, if this restraint be too prolonged, an overcharged state of the nervous system. It is such a state as we see exemplified in the caged quadruped of active habits, when it seeks to relieve it by converting the nervous into the muscular force to the extent permitted by its prison, either executing a succession of bounds against the prison-bars, like the agile leopard, or stalking, like the lion, sullenly to and fro.

"If the active child be too long prevented from gratifying the instinctive impulse to put in motion its limbs or body, the nervous system becomes overcharged, and the relief may at last be got by violent emotions or acts, called 'passion' or 'naughtiness,' ending in the fit of crying and flood of tears.

"But all these impediments to a healthy development of the nervous system might be obviated by regulations, based on the system which you rightly advocate, providing for more frequent alternations of labour and rest, of study and play, of mental exertion and muscular exercise; in other words, by briefer and more frequent periods allotted to those phases of educational procedure, and modified to suit two or three divisions of the scholars, according to age.

"The powers and workings of the human frame concerned in the complex acts and influences, which you have asked me to explain physiologically, are amongst the most recondite and difficult in our science. You will therefore comprehend and excuse my short-comings in trying to fulfil your wish. But, on the main point, I have no doubt that your aim is in close accordance with the nature of the delicate, and, for good or evil, easily impressible organization of the child.

"Believe me, ever truly yours,

"RICHARD OWEN."

It is difficult to separate distinctly the evils arising from the excess of simple bodily inactivity, from the results of the common insanitary conditions of schools—bad ventilation, bad lighting, bad warming, and overcrowding. These, however, are attended by epidemic and eruptive diseases, which ravage the infantile community. Simple constraint appears to be attended by enervation and obstructed functions, and thence maladies of another class. The preventive of these is the occupation of children, with means of physical training, with systematized gymnastics, including swimming, and the naval and military drill. Where there have been good approximations to the proper physiological as well as the psychological conditions, as in the half-time industrial district schools, epidemic diseases have been banished, and the rate of mortality reduced to one-third of that which prevails amongst the general community, and in England and Wales alone, where upward of a quarter of a million of children are annually swept away from preventible disease, which enervates those who survive. Four labourers, who have had the advantage of this improved physical and mental training, are proved to be as efficient as five or more of those who have not. I am prepared to show that by administrative improvements in the application of the principles in question, double the population may be physically and mentally trained well at the expense of educating the existing numbers ill.

On Local Taxation for Local Purposes. By R. DOWDEN.

Dr. Whewell *on the Method of Political Economy.* *By* HENRY FAWCETT, *M.A.*

On Co-operative Societies, their Social and Political Aspect. *By* HENRY FAWCETT, *M.A.*

On the Province of the Statistician. By J. J. FOX.

On Sanitary Drainage of Towns. By J. HITCHMAN.

On the System of Taxation prevailing in the United States. *By* E. JARVIS, *Boston, U.S.*

On Serfdom in Russia. By DR. MICHELSEN.

On the Economical History and Statistics of the Herring. By J. M. MITCHELL, *F.R.S.S.A., one of the Secretaries for Foreign Correspondence of the Society of Antiquaries of Scotland, &c.*

The author said that he read this paper with the view of drawing public attention to the great national importance of the Herring Fishery on the British coasts; and stated that the propriety of affording every encouragement and protection to it has been already affirmed by this Association, in its proposing for one of its objects "The improvement and extension of the British Fisheries;" and the author, in pointing out its importance, quoted the following extract from Baron Cuvier's 'Natural History of Fishes,' vol. xx. pp. 30, 31:—

"Par son inépuisable fécondité le hareng est une de ces productions naturelles dont l'emploi décide la destinée des empires. La graine du cafier, la feuille du thé, les épices de la zone torride, le ver à soie, ont moins influé sur les richesses des nations que le hareng de l'océan septentrional; le luxe ou le caprice demandent les premiers, le besoin réclame le second. La pêche de ce poisson fait partir chaque année, des côtes de France, de Hollande, des Iles Britanniques, des flottes nombreuses pour aller chercher dans le sein d'une mer orageuse, la moisson abondante et assurée que les légions innombrables présentent à la courageuse activité de ces peuples. Les grandes politiques, les plus habiles économistes, ont vu dans la pêche du hareng la plus importante des expeditions maritimes; ils l'ont surnommées la grande pêche. Elle forme des hommes robustes, des marins intrépides, des navigateurs expérimentés. L'industrie que s'empare des produits de ce pêche sait en faire l'objet d'un commerce, source des richesses inépuisables."

Many Acts of Parliament for the purpose of encouraging the fishery, from an early period downwards, had been passed by the Legislature; but, owing to the want of the knowledge of the natural history and habitat of the herring, they proved either injurious or abortive, although bolstered up with bounties and premiums; and the fishery would not have become of any importance had not a local board of unpaid Commissioners been established, with efficient officers acquainted with the localities, so that the fishery might be prosecuted with success at the properly ascertained seasons. The Board was established in 1808, and its beneficial operations would be proved by the statistics of the progress of the fishery; and it will be seen that this fishery became, and is now, one of the greatest and most prosperous in the world, and is now only in danger from improper interference, if it is not guarded and controlled by the influence and opinions of scientific and intelligent men, such as are found at this Association.

To prove the great interest that is taken by other maritime nations in the Herring Fishery, he stated that an interesting discussion took place at the French Academy in 1855, on the question of the migration of the herring, with no satisfactory results, from the want of the knowledge of facts: also, that the Government of Norway had been occupied for several years past in legislating with the view of promoting the Herring Fishery on the coasts of that country; and that in Sweden an elaborate report had been prepared, by the authority of the Government of that country, by one of the heads of the civil department, M. von Wright, with the view of obtaining information as to the cause of the total disappearance of the vast shoals of herrings that formerly visited the Swedish coasts; and that the Government of Holland is anxiously occupied in obtaining information on the subject, and has employed scientific men to investigate the subject of the visits of the herrings, and to prepare reports. The results of these observations, made on board of forty-five of the Dutch fishery busses, are given in a work published by the authority of the Dutch Government, which has been thought of such importance that the British Board of Trade has ordered a translation of it to be made and published for general information; and it is important that it should be known that this movement of the Government of Holland is caused by the lately rapid declension of the Dutch Fishery, and that Government, seeing the rapid progress of the British Fishery on our coasts, has established a system of superintendence and regulation similar to that so successfully promoted by the Fishery Board.

He said that there were many subjects for inquiry which do not properly belong to our Fishery Board, the Commissioners of which and their officers have special duties to perform under legislative enactments, and it may therefore be considered as a reproach to this country, which gains so abundant a supply of food of the best description, while at the same time securing a large force of useful mariners ready to defend our coasts, and in the day of peril to man our navy, that no efficient efforts have yet been made to elucidate the natural history of the herring.

At the present time we seem to pay too little attention to the fostering of our native industry; it is surely obvious that in encouraging the search for gold in our colonies, we are losing, or sending away from our own country, some of the most enterprising and industrious of our inhabitants, not easily to be replaced; while by encouraging the search for the golden treasures on our own coasts, as truly said by the distinguished author, Cuvier, we create those men of so much value to a maritime country—"INTREPID AND ROBUST MARINERS," besides adding every year additional SUPPLIES OF FOOD and "INEXHAUSTIBLE RICHES."

To prove the great advantage of the system of superintendence and inspection of the Fishery Board and their officers, some statistics were given of the progress of the Fishery: among others the following:—

When the Fishery Board was first established in 1808, the quantity of herrings cured and salted in barrels was 90,185 barrels, while in 1855 the quantity cured was 766,703 barrels; and adding the quantity sold fresh, 130,759 barrels, we find the total quantity of herrings caught in that year was 897,462 barrels—yielding at a moderate calculation the value of one million sterling, which may be safely taken as the average annual value of the herrings fished on the coasts of Scotland, without calculating the quantity caught at Yarmouth and other places on the English and Irish coasts, which are principally sold fresh or smoked.

Before an efficient system of legislation and regulation was adopted in this country, the demand from abroad was inconsiderable, but it has annually increased since: for instance, in 1812 the quantity exported to the Continent was only 4720; in 1815 it amounted to 35,891; in 1840 to 82,351; in 1845 to 143,754; in 1850 to 257,108; and in 1855 the quantity exported was 344,029. And to show how rapid the progress has been in foreign markets of the sale of British herrings, he gave the amount of the British, Dutch, Danish and Norwegian herrings imported into one of the largest exporting towns in Prussia (Stettin) in successive years.

In 1825 there was imported there—from

	Great Britain.	Holland.	Denmark.	Norway.
	18,160	4295	1960	6,758
In 1845	81,189	2457	307	44,264
In 1850	116,538	508	470	12,567

and in 1855 the quantity of British herrings amounted to 160,572 barrels—about nine times the quantity sent in 1825 to Stettin; and as the herrings are carefully separated, assorted and packed into proper-sized barrels, cured under the eye of the inspecting officers, the British herrings have become known, in consequence, as a safe and staple article of commerce, and are imported into various other ports; for instance, there were exported to the following ports in 1855—

Königsberg	14,417
Danzig	59,204
Hamburg	26,774
Harburg	60,377
Bremen	6,754
Rotterdam, for the Rhine	7,955
Other ports	8,244
Stettin	160,572
Making a total of	344,207

And it is interesting to know that at the fishery stations in Scotland there were employed in the year referred to, Fishing Boats 11,251, the tonnage being 77,794; and the fishermen, coopers and others employed, amounted to 91,139, of which 91,139 people directly employed, 39,266 were fishermen. These statistics apply to the Scottish coasts only, where the greatest shoals of herrings resort; but there are other places, as already stated, such as Yarmouth, where many of the fishermen are occupied in fishing herrings in the usual seasons.

It is necessary that the truth should be known as to the progressive prosperity and increase of the Herring Fishery, because there are some authors who are inclined to depreciate our national productions and progress; for instance, we find McCulloch, in his 'Dictionary of Commerce,' which is considered a text-book and standard work by a certain class of readers, saying "the Dutch have uniformly maintained their ascendency in the Herring Fishery since the earliest period," and that "ours remains in a very unhealthy and feeble state."

As already stated, the Dutch Herring Fishery is in a declining state, and instead of 300 busses proceeding annually to the fishery, as was the case not many years ago, the number has been gradually decreasing, and does not now exceed 60 busses; but on our coasts great prosperity is evident from the progress of the population, the increase of towns and villages, and from the comfortable state of the fishermen and their families, and the great circulation of wealth that must exist by an annual increase of one million sterling taken out of the sea on our own coasts.

The value of this great fishery should teach us the propriety of carefully fostering and protecting it; and to enable us to do so efficiently, we must have some knowledge of the natural history and habits of the herring, as well as accurate statistcis. He said he was prepared to prove that the herring was a native of the seas adjacent to the coast to which it resorted; and in conclusion, he said that to promote its prosperity, or even to protect it, legislation was necessary, and power should be given to prevent the disturbance of the spawn, and the indiscriminate destruction of the young herring or fry. The fishery grounds during the proper season should be attended by the proper number of ships of war, to prevent disputes and disturbance among the fishermen, and to prevent the large fishing vessels from drifting into the smaller ones. He recommended that the Fishery Board established in Scotland, should be extended to England and Ireland, as calculated to increase the prosperity of the fisheries and the number of fishermen and seamen suitable for the navy.

Before concluding he produced a copy of a letter written by him to the Right Hon. the Lord Advocate of Scotland, to prove that it is absolutely necessary for the protection of the fishermen and the merchants that the system of inspection by the Fishery Officers be continued to preserve order among the fishermen during the fishing season, to prevent the fishermen using illegal nets, and to prevent the fishermen being defrauded by illegal measures; and more particularly as the merchant buys perhaps several thousand barrels at a time, that the necessity of opening the barrels and seeing the herrings may be avoided; and the various onerous duties of the officers he thus enumerates:—

"1. They are the police of the fishery, who maintain and have the power to enforce order. Much fraud and disorder existed before the officers were appointed; at present such cannot exist without being repressed. [This may be said to be the only constabulary force paid out of the national funds in Scotland, and costs only £14,000 per annum. The constabulary force in Ireland, paid out of the national funds, costs £650,000 per annum.]

"2. They protect the fishermen in this way,—the measure or cran by which they are paid for their fish must be of legal size and branded. Formerly it was often made too large, and the fishermen were defrauded.

"3. They prevent the meshes or squares of the net from being made below the proper size, which, if so made, would take the young and inferior herring.

"4. They see that the fishermen do not fish during the day and on Sunday. In a paper I read at the Literary Institute the other day, I proved that three important fisheries were annihilated by this practice of fishing during the day.

"5. They prevent, as far as they are authorized by law, the destruction of the fry and spawn, which would diminish or annihilate the herrings.

"6. They point out to the tyro fish-curer the mode of cure.

"7. They see where the fishing localities rise into importance, so that they can point out where creeks may be improved, by forming fishing harbours and shelter for the fishermen.

"8. They see that the herrings are cured within twenty-four hours after being caught.

"9. They see that the different kinds of herrings are properly separated and packed in different barrels.

"10. They see that they are properly gutted.

"11. They see that a sufficient quantity of salt is put into the barrels with the herrings.

"12. They see that they are properly packed in the barrels.

"13. They see that they are, after ten days, properly filled up with a sufficiency of herrings and pickle.

"14. They see that the barrels are of the proper legal size.

"15. They see that the barrels are of the requisite materials and strength, which they formerly were not.

"16. They see that no branded barrel is used a second time to cover inferior fish.

"17. And when all the requirements are attended to, they apply the brands to the various descriptions of herrings as they have been assorted. There are several brands applicable to the different kinds—the highest being the crown brand and the word 'full.' The applying the crown brand is a proof of the officer having watched the progress of the cure. It is, in short, the mere *Finis coronat opus*—the *opus*, or work, has been going on since the herrings were fished, and the crown proves that the herrings are merchantable; but the various operations require careful attention during the whole year."

On some suggested Schemes of Taxation, and the Difficulties of them.
By W. NEWMARCH.

Hints on the best Plan of Cottage for Agricultural Labourers.
By HENRY JOHN KER PORTER, *M.R.I.A.*

The present condition of the dwellings of farm labourers requires, I believe, with some exceptions, improvement no less than the abodes of the labouring classes in large towns. The drainage and ventilation are generally admitted to be imperfect; but the evil of too much cold air is severely felt in some districts with which I am acquainted; I have found cottages built of what I have seen in New Zealand and Australia, and there called "wattle and dab" or wicker work, covered with untempered mortar: these walls cannot keep out the piercing cold in winter; the framework on which the roof rests frequently gives way, and the doors and windows cannot be kept water-tight.

I have turned my attention towards their improvement. I have had the large heavy thatched roofs, where they are good, supported, while new brick walls have replaced "the wattle and dab," and new doors and windows have been added. I found this alteration cost from £10 to £12 each cottage, and the occupiers were quite willing to have 5 per cent. on the outlay added to their rent.

With reference to new buildings, I have the pleasure to present to this Section of the British Association the drawings of a cottage which I found from practical experience to be the best suited to the labourer in rural districts. It combines the advantages of at least three airy bed rooms, a lofty kitchen or living room, and an apartment which may be turned either into a parlour or a bed room, where the family is large; or if neither of those apartments are required, it may form an outer kitchen or scullery. A lean-to is added to the end of the house, which forms a barn to hold the gleaning, the fuel, or other matters, without which no labourer's cottage can be kept neat and comfortable. Two peculiar features in the cottages I have built I beg to refer to. Ventilation is secured by a 4-inch square opening near the ceiling in each apartment; this opening leads the foul air into a small flue of the same size carried up to the gable of the house, and finding egress in a narrow opening in the outer side of the wall. When the cottage is built of brick, this adds nothing to the expense; when built of stone, it is only the additional cost of the round tiles for forming the flues. Several of these flues may lead to the upper one, which of course must be proportionably enlarged to carry off the increased quantity of air. In Ireland I built twenty dwellings in a double row of houses, at one side opening into a court yard, the other into the street of a large market town. Fevers prevailed in the following year, and several deaths occurred amongst the labouring classes, and not one death amongst the 100 individuals occupying those houses. I built two villages on the same estate, and the medical gentleman whose duty it was to visit the labouring classes on that property, bore testimony to the value of the system adopted for ventilation. The other peculiarity in these houses was the mode in which the window-sashes were made. Every one acquainted with English cottages of the last half-century, is aware of the misery and expense of lead lights, never keeping out cold and always wanting repair. Metal has been substituted, and these are often so imperfect that they fit badly and neither exclude wet nor cold; it is the case in school-houses in the parish in which I reside, and there was no expense spared in their erection. To avoid these difficulties, I adopted wood for the outer part of the sash, the inner divisions being formed of ¾ inch hoop iron cut half through where they intersect, and thus forming one of the strongest sashes possible, with the advantage of being able to add to or take from the outer sides of the sash, to make them fit tightly; they open on a pivot let into the sash on each side, thus giving the whole size of the window, when necessary, for the admission of fresh air. I have made a very rude attempt at a model before breakfast this morning, but it will serve to show the plan of forming the window with the hoop iron. I have erected one such cottage in the county of Huntingdon, upon the estate which is placed under my management as agent; and so many tenants have requested two houses each on their farms, that I am about to build several more, the money being advanced by the Land Improvement Society, to be paid by instalments in 31 years, thus giving the estates, the tenants, and the labourers the immediate benefit of the improvement, while the proprietor of the estate, who is only tenant for life, will not be obliged to expend so very large a sum, which might have the effect of curtailing other improvements. The tenants in every case have agreed to pay 5 per cent. increased rent for the outlay, and these rents will be paid by labourers, who gladly settle down where they find constant employment and comfortable and healthy dwellings.

On the Systems of Poor Law Medical Relief. *By* F. PURDY.

Notes on various Efforts to improve the Domiciliary Condition of the Labouring Classes. By HENRY ROBERTS, *F.S.A.*

It is only within the past fifteen or twenty years that much attention has been directed to this subject, and considering its importance in regard to a very numerous class of the community, I trust that a brief statement of facts, drawn from experience, and tending to show by what means the object is most likely to be obtained, will not be deemed foreign to the investigations of that branch of the British Association which is devoted to Economic Science and Statistics.

That an undertaking which in its commencement may appear very easy should in its progress encounter some unexpected difficulties, is of such common occurrence, that it would be almost an exceptional case were it otherwise in this instance. But to be daunted by difficulties is foreign to the character of Britons, and it should be so especially when the object aimed at is the benefit of our fellow-creatures.

I assume that something of the actual domiciliary state of vast masses of our fellow-subjects is known to most, though but few have sounded the depths of its misery or of its degradation, and none can fully estimate its evil results. Whilst on the Continent for the recovery of health, I have seen and heard it so often referred to, that, when recommending the subject to the attention of influential persons in different countries, I could not but think of those words, "Physician, heal thyself."

The first associated efforts of a practical character were commenced in England, shortly after the investigations made by Government authority into the state of the poor, subsequent to the first outbreak of cholera in the metropolis. Two societies were then formed by philanthropic individuals, with a view to work out and to exhibit a practical remedy for the great social evils resulting from the condition of the dwellings of the working classes,—a remedy which would commend itself to extensive adoption, and be the means of stimulating the owners of existing houses from self-interested motives, to improve and render them healthy abodes, and afford the evidence of practical results in support of an appeal to the legislature for a somewhat unprecedented interference with private property.

The first established of these Societies, though the second to commence building, which it did in 1845, is the Metropolitan Association for Improving the Dwellings of the Industrious Classes. Up to the present time it has expended on its ten distinct ranges of dwellings £89,613 14*s.* 10*d.*, of which £71,328 2*s.* 6*d.* has been laid out on six separate blocks of dwellings in different parts of the metropolis, which accommodate 395 families; the net return received from them, for the year ending 31st March last, after deducting all current expenses and repairs, amounted to £2687 4*s.* 4*d.*, being about 3¾ per cent. on the outlay. On two lodging houses for single men,—one of them new, which has accommodation for 234, and the other old, which provides for 128,—the return, owing to the want of sufficient occupants, has been very unsatisfactory; such indeed as to involve a considerable loss, which proves that the buildings are either too large, or in some way unadapted to the class of men frequenting their neighbourhood.

It is worthy of observation that the same result has attended a similar lodging house at Marseilles, built outside the town, for 150 men, too far from their daily occupation, whilst many such houses elsewhere, on a smaller scale, accommodating from 50 to 100 men, and near to their work, have fully succeeded; in some instances they have been gradually increased, which is the case at Leeds and at Liverpool. Of two adjoining houses, built on the Boulevard de Batignolles in Paris, to accommodate together 203 men, and having on the ground floor a restaurant and café, one was closed two years since. In this instance, however, the failure is doubtless in some degree attributable to defective management.

The second established Society in London, that for Improving the Condition of the Labouring Classes, commenced its first building in 1844. It has constructed four distinct ranges of new buildings, which accommodate 97 families in separate dwellings, provide 94 rooms for single women, and lodgings for 104 single men, as well as a public wash-house with baths. It has also renovated and fitted up, in three distinct localities, old houses which lodge 158 single men. These several dwellings and lodging houses have all been in full occupation since 1851. Within the past six years, three entire courts in different localities have been taken by the same Society; and the condition of the houses, which were indescribably filthy, and occupied by the lowest class of tenants, has been completely changed. The number of rooms collectively contained in these courts is 275, and there is also a single men's lodging house with 40 beds. The total expenditure on these new and old buildings, with the land, has been £43,631 17*s.* 3*d.*

The form in which the accounts of this Society are presented does not afford the same facility for ascertaining the pecuniary return on the capital invested, as those of the Metropolitan Associations do; and one of its undertakings,—that in Portpool Lane, the Thanksgiving Model Buildings, which was commenced in 1850 with contributions received after the removal of the cholera,—was avowedly of so experimental and mixed a character, that the pecuniary results are not a criterion applicable to other cases, excepting as a caution against providing largely in one building for single women. The average occupation of 64 rooms, which progressed very slowly at the commencement, has not exceeded 50 to 52; and more stringent regulations, with regard to the hours of closing, and more constant supervision than in the men's lodging houses, are proved to be indispensable. The public wash-house and baths, though a boon to the neighbourhood, have not been remunerative.

The receipts and expenses of the different buildings during the year 1852, for which I can personally speak to the management of this Society, having then acted on its committee and as its honorary architect, were,—

		£	*s.*	*d.*
Bagnigge Wells: self-contained houses and flats for 23 families, and rooms for 30 aged females. Outlay on land £1045, building £5025.	Receipts	375	7	7
	Expenses	82	6	9
	Net return	203	0	10
Streatham Street: houses for 54 families built on flats, fire-proof, and with galleries. Outlay, ground rent £50, building £8916 16*s.* 0*d.*	Receipts	724	7	4
	Expenses	224	18	1
	Net return	499	9	3
George Street: lodging house for 104 men, six stories high, including basement offices, and four floors of dormitories. Outlay, land £1200, building £5226.	Receipts	618	11	4
	Expenses	306	6	2
	Net return	312	5	2
Charles Street: lodging house for 84 men formed out of three old houses, renovated and thrown into one. Outlay on repairs and furniture £1163 14*s.* 2*d.*	Receipts	418	0	4
	Expenses	233	5	2
	Net return	184	15	2
King Street: lodging house for 22 men. An old house, on the repairing and furnishing of which £135 was expended.	Receipts	111	9	8
	Expenses	73	13	11
	Net return	37	15	9

The rents received from these houses have varied but slightly since they were opened, up to the present time, and they are generally well-filled, the families changing but seldom. The cost of repairs is not included in the expenses which are above stated; they should be taken as averaging ¾ per cent. on new, and generally from 1 to 2 per cent. on old buildings.

Calculating 4 per cent. interest on the cost of the land, the clear return on the outlay of £19,467 16*s.* 0*d.* on the three first-named piles, which are new buildings, is 5¼ per cent., from which, deducting ¾ per cent. for repairs, leaves 4½ per cent. net. It should, however, be observed, that the return from the Streatham Street family houses is higher than from the other two, amounting to 5 per cent. net, and the rents of the family houses were mostly fixed below those usually paid for similar accommodation. The two lodging houses, which were old buildings and leasehold, yielded a return of about 17 per cent.; and deducting 2 per cent. for repairs, they gave a net return of 15 per cent.

The outlay in putting the three old courts into a good sanitary state, with suitable fittings, including the lodging house, has been £7226 1s. 4*d.*: and the clear return for the year ending 31st December 1858, was £203 14*s.* 3*d.*, from which deducting 1¼ per cent. for the expense of repairs, leaves about 1¼ per cent. net on the outlay.

From these figures it would appear that whilst in the metropolis old buildings may be renovated and fitted up for men's lodging houses, with the prospect of at least a fair remunerative return, although this has not been the case invariably, the putting of old courts and blocks of dwelling houses for families into a good sanitary condition, unless they are obtained at an unusually low price, is not likely to yield a satisfactory return on the outlay, even taking 4 to 5 per cent. as the lowest rate of interest which such investments should yield, after provision has been made for repairs, and a sinking fund to pay off the capital, which there should be, especially in the case of leasehold property.

It is well also to notice that the actual benefit resulting from these efforts has not been conferred to the extent which might be supposed, on those who were the occupants of the courts, when they were taken by the Society, as a considerable portion of them have been ejected, in order not only to reduce the number of occupants to a due limit, but also to secure a more eligible set of tenants.

It may, however, be stated here, that a Society has for the past three years been successfully in operation at Hastings, established mainly through the instrumentality of Dr. Greenhill, and called the Hastings Cottage Improvement Society, which avowed "the fixed determination to spare no pains in securing the main object of benefiting the tenants, and at the same time not to discourage the good cause by a commercial failure." With an expenditure to the present time of £9246 in purchasing and putting old dwelling-houses into good condition, a dividend of 6 per cent. has been paid. Judging from what I have seen of the Society's labours at an early stage, it is simply that of putting the acquired property into the condition which any kind-hearted considerate landlord would desire for his own tenants; and this has been done with as little disturbance of the existing occupants as possible. The operations of this Society derive much advantage from the appointment of two visitors, whose duty is to inspect the houses every fortnight. The formation of a reserve fund at the rate of 1 per cent. per annum, and also of a benevolent fund amongst the tenants, deserve notice.

The physical results obtained by the two Societies in the Metropolis have been of a very marked character. For the four consecutive years 1850 to 1853, the average number of deaths in all their houses was only 13·6 per 1000, as compared with 27 to 28 per 1000 in the districts immediately around them, and of 25 per 1000 in the Metropolis generally, whilst there has been an almost entire freedom from the special diseases to which the lower classes are more peculiarly subject, not even excepting cholera. That such returns should not have been regularly continued by the second named of these societies, is cause for regret. A very beneficial influence has been exercised on the localities in which the houses are situated, especially those occupied by families; and it may be confidently asserted that the most sanguine expectations of their projectors have been realized in every respect, excepting that of their financial returns, and the extent to which it was anticipated that the example would be followed.

Had the returns generally proved more remunerative, doubtless a greater number of similar houses would have been built; yet, although they are but a drop in the bucket, when the extent and vast population of London is considered, they are not, as compared with what has been done at Paris, encouraged by a large government subvention, by any means as insignificant as might be inferred from a remark made in the last number of the Quarterly Review, that "the wants of the displaced poor have with us been utterly neglected." It is too true that in the Metropolis of Great Britain, as well as in that of France, the formation of new streets, and the removing masses of miserable dens, has only increased the evil, by crowding yet more those that remain. I can, however, after minutely examining all which had been done or commenced in Paris two years ago, and ascertaining the additions since made, confidently assert that England, which took the lead in this effort of practical benevolence, has done much more through the unaided force of that motive, than has been accomplished in France, with the stimulus of a government subvention of 10,000,000 francs.

The number of improved dwellings for working people which have been constructed in London, either by local associations, or by individuals, following more or less closely the plans of those built by the two societies before referred to, forbids their detailed notice; they may be learnt from my paper on "the Improvement of the Dwellings of the Labouring Classes," given in the Transactions of the National Association for the promotion of Social Science for 1858. On this occasion I shall only allude to such of them as especially illustrate the points which it is the main object of this paper to prove.

At Shadwell, close to the line of the Blackwall Railway, a number of miserable dwellings, tenanted by the lowest class of persons, came by inheritance into the possession of a private gentleman, W. E. Hilliard, Esq. of Gray's Inn: actuated by the most philanthropic views, he decided on endeavouring to improve, not only his own property, but also by example the immediate neighbourhood, and his efforts have been crowned with signal success. The old dwellings have been replaced by an entire street of considerable length; on both sides of which houses for accommodating in the whole 112 families have been built, on the general plan of H.R.H. The Prince Consort's Exhibition Model Houses 1851, with an open staircase, giving access to each pair of upper floor tenements. The twenty-eight blocks of four houses cost £487 each; and after allowing for ground rent and all charges, I can state, on the authority of the owner, that "they continue to pay upwards of six, in fact nearly seven per cent. as a net return on the investment; and what," he adds, "is perhaps of more consequence, they are almost constantly let, and are appreciated by the tenants, who, as a rule, are pretty stationary, and not migratory, as that class frequently are.

"We have before us in this case, an outlay of nearly £14,000 on new buildings which contain 448 rooms, kitchens or sculleries included, yielding from 6 to 7 per cent., whilst we have seen that the cost of obtaining and putting into sanitary condition three old courts, which contain 275 rooms, and a lodging house with 40 beds, has been upwards of £7000; and in that instance the return on the outlay has been 1¼ per cent., after deducting 1½ per cent. for repairs, but making no allowance for a sinking fund."

The Strand Building Company, on their houses for 25 families in Eagle Court, has last year paid a dividend of 4½ per cent. to the shareholders.

The Victoria Lodging House for married soldiers, built by an association of officers of the battalion of Guards, near the Vauxhall Bridge Road, and containing 54 tenements or 112 rooms, was the first practical result of the interest manifested in this object by H.R.H. The Prince Consort in connexion with the Great Exhibition. I allude to it partly as showing how justly the late Duke of Wellington estimated the probable effects of placing that small building in the barrack yard at Knightsbridge, when, as Commander-in-chief, he objected to the situation lest it should cause a feeling of dissatisfaction in the army, with the want of any accommodation for married soldiers; an evil which the Marquis of Anglesea told me His Grace apprehended the country to be then unprepared to remedy. Since that time, separate dwellings for the married non-commissioned officers and men of the regiment stationed at Chatham garrison, as well as for the engineers, have been built; and during the present session of Parliament £30,000 have been voted for married soldiers' quarters.

The Windsor Royal Society, established in 1852, has now £9000 invested in new cottages and in two lodging houses, the net returns from which enable them to pay a dividend of 4 per cent. to the shareholders.

At Liverpool, on a range of dwellings for 23 families, built in Upper Frederick Street after the general plan of The Prince Consort's Exhibition model-houses, 4¾ per cent. is realized. The Association at Brighton has also built one block of six houses on the same plan, and they pay a fair return on the cost.

Not fewer than twenty societies for providing improved dwellings for the working classes have, to my knowledge, been established in various provincial towns in England; and whilst their operations are, without exception, beneficial in regard to the occupants, the pecuniary results have varied considerably. In such undertakings, competent skill and watchful supervision are most important elements of success. In order to show what may be done with sound judgment and careful management, I instance one example, in addition to those already given; and as that is taken from Scotland, I may observe that the urgent necessity for such efforts is as great in the two sister kingdoms as it is in England.

The Pilrig Model Buildings, near Leith Walk, Edinburgh, were commenced in 1850; they consist of forty-four dwellings in three blocks, with access on both sides, the upper floor tenements being approached from the opposite side to that on which the ground floor tenements are entered. The greatest economy, consistent with fitness and durability, was maintained in the construction, so that the total cost of the forty-four houses, including drains, &c., was only £4052 15*s.* 9*d.*, being on an average about £92 per house, with scarcely any extras. The rent of the whole is £303 19*s.* 0*d.*, varying from £5 5*s.* per house up to £9 15*s.*, one half of them not exceeding £6 6*s.* per house. Higher rents might have been charged had not the committee desired to benefit a class of persons who could not afford to pay more. After deducting all expenses,—feu duty £22 14*s.* 10*d.*; insurance £5 12*s.* 6*d.*; rates and taxes £13 11*s.* 2½*d.*; repairs £13 4*s.* 7*d.*; management £21 6*s.* 3*d.*, and paying a dividend of 5 per cent. (less income tax) amounting to £196 16*s.* 6*d.*,—a balance of £30 13*s.* 1*d.* was last year added to the sinking fund, from which sundry expenses, such as painting and papering, are defrayed. This fund now amounts to about £150. Having had the opportunity of seeing these houses when returning from the Aberdeen Meeting last year, I refer to them with pleasure, as in many respects worthy of imitation, and am not surprised at hearing that the demand for them is generally at least six times equal to the supply.

The facts given thus far, refer exclusively to buildings in towns: with regard to country districts, in which there is an equal necessity for exertion, the number of improved cottages built by landed proprietors, as well as by other large employers of working people, such as manufacturers, railway and other public companies, owners of collieries, mines, quarries, &c., has within the past twelve years been very considerable; and it is to the increased feeling of responsibility in this respect, as well as to more enlarged views of their own interest on the part of employers, that we must mainly look for the much needed improvement in the domiciliary condition of our rural population, and of those whose industrial employments are remote from towns.

In thus saying I do not forget that in many places Benefit Building Societies present a useful machinery for enabling the working classes to obtain improved dwellings, and that much good may result from judicious advice given to their members in the selection of such plans as will enable them to obtain a healthy and convenient home. In many places on the Continent, societies have, within the past ten years, been formed by philanthropic persons to build suitable houses for working people, and likewise to afford facilities which enable their occupiers, by small periodical payments in addition to the rent, to become the owners of their own dwellings; the parties who advance the money being satisfied with 4 per cent. interest, and the security of a sinking fund to pay off the capital. Such buildings act as a savings' bank, promoting sobriety and habits of forethought.

The beneficial effects resulting from a diffusion of sanitary knowledge amongst the working population generally, and the importance of their being led to understand and feel how greatly they are personally interested in the possession of a wholesome dwelling, ought on no account to be overlooked by those who seek to promote this object. Great evils which have arisen out of the selfish system, pursued in some *close parishes*, of pulling down cottages in order to obtain relief from a burden which is thereby thrown on a neighbouring parish, loudly call for legislative interference.

In regard to populous towns, and the metropolis more especially, the facts which have been stated lead to the conclusion, that the evils of overcrowding which result from a demolition of large masses of dwellings of the working classes, effected for the carrying out of public improvements, can only be prevented by a parliamentary enforcement of the construction of suitable buildings in the place of those destroyed. A standing order of the House of Lords for the investigation of such cases exists, but it appears thus far to have been practically a dead letter.

Whilst the pressure consequent on these destructions is felt by all classes of the working population within their influence, facts have been brought to light by experience, which conclusively prove that no efforts of societies, or of individuals, can remedy the existing state of wretchedness, which is a consequence of sanitary defects and of overcrowding in the lowest class of dwellings. Nothing can effect this much-needed remedy, but the extension to all tenements in towns and thickly populated neighbourhoods, which are let at low weekly rents, of such legislative interference as is universally admitted to have been of the greatest benefit in the case of common lodging houses. Within the limited jurisdiction of the Corporation authorities in the City of London, such a power was conferred in 1851, and it is judiciously exercised under the supervision of the Medical Officer of Health, to the great benefit of the poor, and with a marked diminution in the returns of mortality, which have fallen since that date from 25 to 23 in 1000.

In the case of all new buildings, proper drainage should be enforced by authority, prior to their commencement; the want of it is a most fruitful source of sickness, and consequent expense to the public.

In the preceding notes my aim has been to draw only such conclusions as are fully supported by the facts adduced. I cannot, however, omit glancing at this subject from one other point of view, and that the most important in which it can be presented for consideration, its bearing on our fellow-creatures as moral and accountable beings. The experience of a right rev. prelate, when formerly rector of St. Giles-in-the-Fields, one of the most thickly-populated and poverty-struck parishes in London, must give peculiar weight to the following words: "The physical circumstances of the poor paralyse all the efforts of the clergyman, the schoolmaster, the scripture reader, or the city missionary, for their spiritual or their moral welfare..... Every effort to create a spiritual tone of feeling is counteracted by a set of physical circumstances which are incompatible with the exercise of common morality. Talk of morality amongst people who herd, men, women and children together, with no regard of age or sex, in one narrow confined apartment! You might as well talk of cleanliness in a sty, or of limpid purity in the contents of a cesspool!"

Our prisons are no longer hot beds of fever* and of moral contagion as they formerly were: may it not be asked in this Association, whether, with the advance of science, the reproach to which England is justly amenable on account of the domiciliary state of our labouring population, ought not to be effaced? and, whilst self-interested motives might be urged on many, the divine command, "thou shalt love thy neighbour as thyself," lays a serious responsibility on all who have it in their power to promote an object so indispensable to the well-being of our poorer neighbours.

MECHANICAL SCIENCE.

The President, in opening the business of the Section, took occasion to refer to the great loss Mechanical Science had sustained, since the last Meeting, in the deaths of Brunel and Stephenson. He then made some brief remarks on the recent progress of Mechanical Science, especially in the use of heat to produce motive power.

On the Mechanical Effects of combining Suspension Chains and Girders, and the Value of the Practical Application of this System (illustrated by a Model). By P. W. Barlow, *F.R.S.*

On Rifled Cannon. By Captain Blakeley.

The writer remarked, that to make an efficient rifled gun, no more was needed than to copy any good small rifle in the number and shape of the grooves, degree of twist, and other details, provided one difficulty was overcome, viz. that of making the barrel strong enough. Taking Sir W. Armstrong's 80-pounder as a standard, Capt. Blakeley gave several examples of large rifled cannon on the model of successful small ones, which had given satisfactory results in every way, except that they had failed after a short time for want of strength. Mr. J. Lawrence, in 1855, rifled a 6½-inch gun with three shallow broad grooves, like an Enfield, and fired a lead and zinc bullet, like the Enfield. At an elevation of 5°, the range was 2600 yards—150 more than Sir W. Armstrong's; but the gun burst after about 50 rounds. Mr. Whitworth, after making some excellent small arms and nine-pounders, tried a large gun with 4 inches bore, and sides 9 inches thick; but it burst. He then tried another, 11 inches thick, and it too burst. He had, however, since made a stronger cannon, whose success was absolute proof that the one thing wanting in the other was strength. Capt. Blakeley explained his own method of obtaining strength, which consists simply of building up the gun in concentric tubes, each compressing that within it. By this means the strain is diffused throughout the whole thickness of the metal, and the inside is not unduly strained, as in a hollow cylinder made in one piece. As the whole efficacy of the system depended entirely on the careful adjustment of the size of the layers, Capt. Blakeley said he was not astonished that Sir W. Armstrong had lately failed utterly in his attempts to carry it out, because he did not put on the outer layers and rings with any calculated degree of tension; "they were simply applied with a sufficient difference of diameter to secure effectual shrinkage," to quote his own words at the Institution of Civil Engineers. To show that the late failure by Sir W. Armstrong did not disprove his, Capt. Blakeley's, theory, he quoted official reports of a trial of a nine-pounder made by himself in 1855, which showed an endurance sevenfold that of an iron service gun, and threefold that of a brass gun, as well as of an 8-inch gun, from which bolts weighing 4 cwt. had been fired, and of a 10-inch gun which had discharged bolts weighing 526 lbs. Mr. Whitworth's last new 80-pounder was another instance of the successful application of Capt. Blakeley's principle. To quote Mr. Whitworth's own words,—"It was made of homogeneous iron. Upon a tube having an external taper of about one inch, a series of hoops, each about 20 inches long, were forced by hydraulic pressure. Experiments had enabled him to determine accurately what amount of pressure each hoop would bear. All the hoops were put on with the greatest amount of pressure they would withstand without being injured. A second series was forced over those first fixed." This gun was so made at Capt. Blakeley's suggestion, excepting that the rings were put on too tight, which might prove a cause of weakness. The method of rifling adopted by Capt. Blakeley cannot be made intelligible without a diagram; but it may be described as a series of grooves of very shallow depth, so arranged as to exert a maximum force in the direction of the rotation of the bullet with a minimum force in a radial or bursting direction. Capt. Blakeley exhibited in the court of the building in which the Section met, a 56-pounder, constructed on his own plans, from which he had thrown shells to a distance of 2700 yards, with only 5° of elevation, which was stated to be a range 300 yards greater than that of Sir W. Armstrong's 80-pounder.

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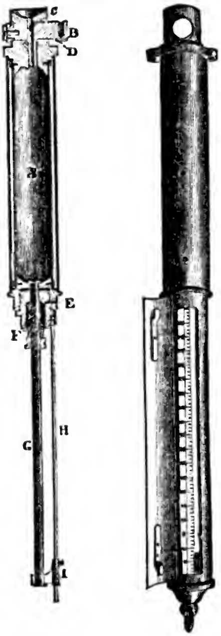
* At the black assizes held in Oxford in July 1577, the gaol fever spread from the prisoners to the court, and within two days had killed the judge, the sheriff, several justices of the peace, most of the jury, as well as a great number of the audience, and afterwards spread amongst the inhabitants of the town.

On a deep Sea Pressure Gauge, invented by Henry Johnson, Esq. *Read by the* Rev. Dr. Booth, *F.R.S., &c.*

In deep sounding the pressure is too intense to admit of measurement by the compression of any highly elastic fluid in a small portable instrument. Water, however, possesses a slight degree of elasticity, and an instrument recording the compression of an isolated portion of water by the pressure of the sea, will show the compression of the water at the depth to which it has been lowered.

Mr. Canton, who in 1761 communicated his observations to the Royal Society, found in water, compressed under a glass receiver, by the pressure of an additional atmosphere, a diminution in bulk equal to one part in 21,740; and in water placed under a receiver a similar expansion when the air in the receiver was exhausted. Mr. Perkins, more recently, found a diminution of bulk of $\frac{3}{30}$ths in water under a pressure of 1120 atmospheres. The theory of increased pressure at great depths is corroborated by a very interesting experiment made by the distinguished voyager Rear-Admiral Sir James Clark Ross, who lowered, to a great depth, a bottle fitted with a tube, with a cork suspended so as to enter the tube, if, as anticipated, the water in the bottle, condensed under heavy pressure, should expand upon the raising of the bottle and the removal of the pressure. Upon the return of the bottle to the surface, it was found that the cork had been forced some distance along the tube, and the amount of compression and of subsequent expansion were thus roughly estimated.

The pressure gauge exhibited, may, in its present form, be considered as a small hydraulic press; of which the ram is forced into the cylinder by the increasing pressure of the sea when sinking, and expelled by the expansion of the water in the cylinder when rising. It consists of a small tube or cylinder having at one end a tap through which water is admitted; the tap having in addition to the opening admitting water, a smaller opening for the escape of air. At the other end of the cylinder is a packing-box, through which a round bolt or solid piston passes. A scale by the side of the piston contains the degrees of compression, and an index at the further end of the scale is drawn along the scale by the piston when forced by increasing pressure into the cylinder, and secured by a spring in its position, where it remains when the piston is pushed back by expansion of water in the cylinder to its former position. The scale and index are protected by a tube screwed on to the cylinder, and the cylinder is protected from the risk of indentation by an outer tube. In an experimental instrument the packing-box has remained water-tight under the application of a pressure of 1000 lbs. to the square inch on the piston; so that the isolation may be considered sufficiently perfect, as in actual use this pressure on water in the cylinder would be counterbalanced by the external pressure of the ocean. The packing-box is just large enough to admit the packing, which consists of vulcanized caoutchouc rings, stretched upon the piston, and consequently adhering closely to it. A moderate application of the packing-box screw presses these rings against the packing-box, and a perfect isolation of the water in the cylinder is thus obtained. A slight lubrication of the rings, by the addition of a small quantity of lard between them, renders the amount of friction attending the motion of the piston very trifling.



A—Cylinder.
B—Tap.
C—Opening in Tap for admission of water.
D—Opening in Tap for escape of air.
E—Packing-box.
F—Packing-box Screw.
G—Piston.
H—Scale of compression.
I—Register Index.

In ascertaining the pressure of water, the amount of friction overcome should be added to the compression recorded by the index, to obtain the total amount of pressure. Some portion of the diminution of bulk will probably be occasioned by variation of temperature, and which causes a greater variation in bulk at high temperature. As 4000 parts of sea-water at the temperature of 86° Fahrenheit, contracted to 3987 parts at the temperature of 65°, being $\frac{13}{4000}$ parts for 21°; while from the temperature of 65° to 35°, the diminution to 3977 parts was only at the rate of $\frac{10}{4000}$ parts for 30°,—the expansion and contraction of the cylinder by variation of temperature counteract the variation of water to a very small extent, being about $\frac{2}{4000}$th parts for 40° Fahrenheit.

The experimental instrument indicates a compression of about one part in 20,000 per atmosphere (estimated at 15 lbs.) at the temperature of 60° Fahrenheit.

The experiments will be varied by the use of a glass bulb with a long stem, finely graduated, with a stopper of vulcanized caoutchouc, and in the tube an elastic ring which is pushed during compression by the stopper towards the bulb, and remains to mark the degree of compression.

On Road Locomotives. By the Earl of CAITHNESS.

The author referred to what had hitherto been done in this direction, and the importance of attention being given to the construction of them as feeders to the Railway system. He described the arrangement adopted in one which he had had built for his own use, and which was successful. The carriage was exhibited in action, and made several trips in the street under his Lordship's guidance. In the discussion which took place, great stress was laid on the importance of Parliament reducing the turnpike tolls in respect of such carriages, which, in reality, were in no way injurious to the road.

On Water Meters. By DAVID CHADWICK, *Assoc. Inst. C.E., Manchester.*

After pointing out the defects in some of the water-meters at present in use, he described the high-pressure piston water-meter of Messrs. Chadwick and Frost, which obviated these defects, and secured the correct measurement of water at all pressures and velocities of discharge, without the use of tumbling-levers, springs, or flexible diaphragms, by a more compact and simple arrangement than any other piston meter; but, without a diagram, it would be impossible to make its construction intelligible.

A New Mode of obtaining a Blast of very High Temperature in the Manufacture of Iron. By E. COWPER.

The blast is obtained by an adaptation of the principle of Siemens's regenerative furnaces. A hot blast of a temperature of 1800° Fahrenheit can readily be obtained, and this without the destruction of iron tubes—the substance used in contact with the air being the most refractory fire-brick. This mode of obtaining a blast was in successful operation at Messrs. Cochran's iron-works. The temperature of the blast could be regulated to any required degree. The heat might be obtained with far greater economy than by any method hitherto known.

The Cylindrical Spiral Boiler. By JOHN ELDER.

[A communication ordered to be printed entire in the Transactions of the Sections.]

The object of the construction of this boiler is to obtain a form with all the useful properties of the simple cylindrical high-pressure boiler on shore adapted to steamships.

The following advantages appear to be attained over the ordinary marine boiler, namely:—

1. A form of boiler capable of carrying higher pressure, and presenting more heating surface, and of a more effective description from a given weight of material.
2. A boiler capable of being easier cleaned and repaired in both water and fire spaces.
3. A boiler capable of producing superheated steam to any practical temperature.
4. A less average specific gravity of water whilst working at sea with the usual amount of feed and blow-off, and a more perfect combustion chamber, and better formation of flue surface.
5. The pressures being altogether internal, the boiler is not liable to collapse, a danger lately ably demonstrated by Mr. Fairbairn; and as the diameters of the various cylinders are reduced to the minimum size for permitting the tradesmen to pass through, clean and repair them, the boiler, when formed of ordinary thickness, possesses enormous strength without stays.
6. The expense of the boiler per square foot of heating surface is about the same as that of the ordinary boiler, and is capable of carrying five times the pressure.

The general construction of this boiler is as shown in the accompanying plans, and as follows:—

There are twenty-four round boilers or tubes, of not less than nineteen inches in diameter, twenty-two of these forming, when bound together, a cylindrical vertical shell; the twenty-third, a centre boiler concentric to that shell; and the twenty-fourth, a spiral coil-boiler winding spirally round between the centre boiler and those composing the circumference shell: these boilers contain the water, and the spaces between them the fire.

The feed water passes first into the spiral compartment, or No. 24, and from it into the centre compartment, or No. 23, and then into each in rotation, and blows off at the last compartment, or No. 1, thus rendering the water in No. 24 nearly pure sea-water, and gradually from compartment to compartment more dense, till it blows off at No. 1 at the usual density, and thus makes the average specific gravity of the water less than usual.

The twenty-two outside boilers are 24 feet long, 19 inches diameter, and $\frac{5}{16}$ of an inch thick; the bottom ends are conical for 3 feet, and kneed outwardly to give a larger diameter of furnace, say 12 feet diameter. There is a furnace-door for every alternate tube, or say, eleven furnace-doors, equally divided round the base of the boiler, giving great facility to the firemen for doing their work efficiently. In firing it is proposed to charge all the fresh coal round the circumference of the fire, in order that the hydrogen of the coal may be consumed separately from the carbon; and as the furnace has great altitude, the combustion will be completed in vertical flames from the coals, and will thus prevent the carbonic acid gas, given out from the combustion of the carbon, coming so much in contact with and preventing the combustion of the hydrogen, as is usual in ordinary furnaces.

The centre compartment, or No. 23, is 30 feet long, 34 inches diameter, and $\frac{3}{8}$ of an inch thick, with 3 feet at the bottom and top, conically reduced to 18 inches diameter, forming a man-hole door; the upper end of this vertical tube forms a reservoir for the steam of the whole twenty-four compartments, and acts as a superheating apparatus, and may be carried up the funnel to the extent necessary to superheat the steam to 400 degrees; the steam-pipe is taken from the top of this boiler to the safety-valve chest, fastened on the front of the boiler low down, which serves as a water-trap during the discharge from the safety-valve chest, the steam-pipe to the engines being taken off the same pipe at a higher level than the escape steam. The spiral compartment, or No. 24, is about 100 feet long, 34 inches diameter, and $\frac{3}{8}$ of an inch thick, made of best iron boiler plate; the ends are conical for 3 feet, formed into man-hole doors; this spiral boiler makes four or five convolutions close round the centre one, and is bound close to the circumferential boilers by hollow stay-bolts, and fastened to the centre one at each end only; in the same manner the steam and water flow through the whole boiler by these hollow stay-bolts or rivets, and complete the entire circulation of water and steam; the whole of these twenty-four compartments or boilers terminate at the bottom, about 1 foot below the fire-grate, and are supported on six stanchions from the ash-pit beneath, making a free passage for the air under the great bar; the circumferential compartments or boilers terminate at the top 6 feet above the ship's deck, and have each a man-hole door forming the cover; the funnel is made conical at the bottom to embrace the internal diameter of the boiler-shell and draw off the smoke in the usual manner: this completes the whole boiler proper; but in order to prevent radiation of heat, a thin outer casing of iron is made (9 inches) clear of the boiler all round, terminating about 7 feet from the stoke-hole floor; and above, at the level of the galley or funnel house, this casing is lined with felt and thin wood to keep the deck and the adjacent parts cool, and retain the heat. The twenty-two straight cylindrical boilers or compartments are constructed in the sides by four plates 24 feet long and 16 inches broad, rolled to a 9½-inch radius curve at the iron works, leaving no plate setting for the boiler maker of this description.

The plates of boiler No. 24, or the spiral compartment, are delivered flat by the iron-maker, and are bent to the spiral curve by one blow of a large spiral concave block falling upon a counterpart convex one, prepared by the constructors of the boiler. This operation has been found to simplify the making of this spiral cylindrical boiler to about the same amount as the straight cylindrical boilers. The conical ends are bent in the same manner as the spiral plates, and the whole work of plate bending is reduced as far as possible to machine work. The products of combustion, after leaving the furnace, have to travel spirally upwards a distance of 100 feet, and must of necessity be continually rotating during that time, and prevent the possibility of any portion passing off without being brought frequently in contact with the heating surface of the boiler; and will therefore be cooled down to the minimum temperature compatible with a given amount of cooling surface, or the greatest quantity of heat extracted from the products of combustion, before their escape to the atmosphere. The soot forming usually inside of boilers will not be so injurious in this arrangement, as it will fall down through the external crevices, and also between the spiral and the centre boilers into the furnace below, and be thrown overboard with the ashes.

This spiral coil and all the heating surfaces will keep more clear of flue dust than usual, and will consequently be more efficient in that respect, as well as save the usual trouble and loss by sponging experienced in the ordinary tubular boilers at sea. Also as the products of combustion must pass off at the rate of at least 7 feet per second in this as in the ordinary boilers, it will take upwards of 14 seconds from the time it leaves the furnace till it arrives at the top of the boiler; whilst if the boiler were of the ordinary tubular type, it would pass in about two seconds along the whole heating surface of the boiler; the gas has therefore seven times more time to give out its heat, and its revolving tendency will not admit of the same strata of gas passing along the passages after it is cooled down, as is the case with the ordinary boiler, but will bring the hot products of combustion usually occupying the centre of the tubes of a tubular boiler in contact with the cooling surfaces, and reduce the whole products of combustion to one temperature before entering the chimney.

In cleaning the salt or sludge out of these boilers, the man- and sludge-hole doors are taken off the top and bottom (and the hose with fresh water may be played down through from the top, and the refuse run out at the bottom). The man in charge can also pass down through the whole boiler, the dimensions necessary for this purpose being made the minimum and maximum of the various compartments of the boiler; and are specially constructed to maintain to the engines steam at much higher pressure than usual, in order to admit of a much larger amount of expansion to be developed by the engines, which are all on the double cylinder expansive principle. The constructors are now making the boilers for three steam-ships on this principle, two of which are for carrying Her Majesty's mails on the Pacific between Valparaiso and Panama (as described by the writer at the meeting of the British Association at Leeds); and it has long been his desire to be able to construct boilers for marine purposes without stays, and with no surface exposed to the collapsing tendency, which in so many cases has been the cause of loss of life aboard of steamships. The boilers now described have no large flat surfaces and no stays, the whole tendency of the pressures being to inflate the boiler plates, and, if possible, to give them a stronger form; the smallest diameter is large enough to give access to the men in charge, and the largest diameter 34 inches and $\frac{3}{8}$ thick,—dimensions that can carry several hundred pounds pressure on the square inch before rupture could take place. Such a form the writer adopts, with great satisfaction to himself, as a constructor sending machinery abroad, where the usual form of boiler gives him considerable anxiety. In comparing the construction of this boiler with that of the ordinary tubular one, in the latter angle-iron ribs and stays now compose a large portion of the weight and expense; contribute no heating surfaces; and if one stay breaks, which is not an uncommon occurrence, the next is placed in great danger; and if it gives way, the whole may follow in rotation, and a serious accident be the result. In the former boiler, however, the plates may be reduced to a very small amount of thickness by tear and wear before explosion could be expected.

Having thus described the objects of the spiral boiler, it may not be out of place to give the following statement of the comparative evaporative power and temperatures of the gases in the furnace and chimney of the spiral boiler, with three of the ordinary types of boiler now in general use.

Fig. 1 is a vertical section of the cylindrical spiral boilers as fitted on board the Pacific Royal Mail Company's steam-ships 'San Carlos' and 'Guayaquil,' by Messrs. Randolph, Elder, &c. Fig. 2 is a sectional plan of the same, taken near the level of the water-line in fig. 1. Fig. 3 is a vertical elevational view of the same—the exterior casings which surround the circumferential vertical tubes (and which are shown in figs. 1 and 2) being in this view removed.

It will be seen from these figures that there are in these boilers 21 tubes in all, viz. 19 circumferential vertical tubes, 1 central and 1 spiral tube.

The three types experimented upon were, first, a common cylindrical land boiler (figs. 1, 2, and 3) 33 feet long, 5 feet 6 inches diameter, with two round flues 19 inches diameter through the centre; this boiler had 40 feet of heating surface to the nominal horse-power of the engine: the two flues contained 20 feet, and the shell 20 feet per nominal horse-power; the furnace was below the boiler at the fore-end, had a fire-grate of 26 square feet; the fire passed underneath the boiler to the opposite end from the furnace, and returned along the sides, and then passed back again through the flues to the chimney. The temperature above the centre of the fire was found to be, upon one occasion, 3200°; at the top of the bridge 1730°; the temperature of the gases gradually reduced as they passed back the remaining length of 26 feet under the boiler and along the side flues, till they entered the centre flues at 1163°, and left them at about 800°. Thus the furnace containing a surface of 2 feet per nominal horse-power reduced the heat about 1500°; the shell of the boiler behind the furnace, of about 18 feet per nominal horse-power, reduced the temperature about 600°; and the flues containing a surface of 20 feet per nominal horse-power reduced the temperature about 350°. The temperatures of the gases in the flues were found to be about the same in the centre as at the top; but at the bottom of the flue the temperatures of the gases were at the fore-end rather less than at the top, but towards the back end the temperature of the bottom of the flues reduced gradually below the temperature at the top to the extent of 300°. Upon another occasion the temperature over the centre of the fire was found to be 3610°; at the top of the bridge 1739°; and the different temperatures of the flues were as indicated in fig. 1, where the average temperatures of the flues at $B^1 = 526°$, $B^2 = 879°$, $B^3 = 937°$, $B^4 = 959°$, and at $B^5 = 981°$. The temperatures at the top of the flues at $C^3 = 982$, at $C^4 = 1034°$, at $C^5 = 1087$. The temperatures at the bottom of the flues at $A^1 = 571°$, $A^2 = 603°$, $A^3 = 678°$, $A^4 = 764°$, $A^5 = 822°$. It would therefore appear that, notwithstanding the large amount of surface in this boiler, the evaporative power is very inferior, as

Fig. 1.

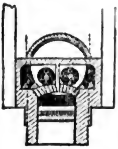


Fig. 2.

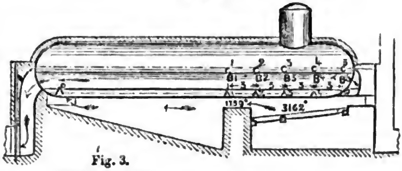


Fig. 3.

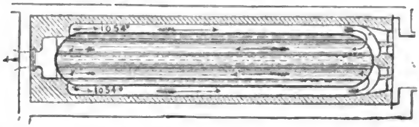


Fig. 4.

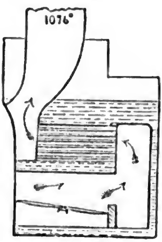
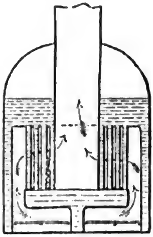
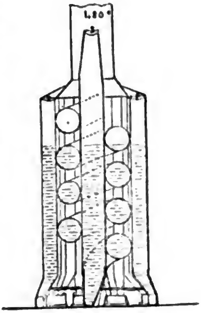


Fig. 5.



the amount of heat taken out of the gases per square foot of heating surface is very small; and that the natural conclusion is that the gases pass along in straight lines, and only the thin stratum in contact with the surface is cooled down. In the results of the spiral boiler (fig. 6) three times the quantity of heating surface was found to reduce six times the quantity of gas from the same temperature of 3200°, to a temperature of 4800 instead of 800°, showing that a more complete turning over of the gases is much wanted in our land boilers. The water evaporated per hour in the land boiler referred to was found by meter to be 2000 lbs., and the coal, best Glasgow quality, found to be 300 lbs. per hour; making about 6¼ lbs. of water per pound of coal. During the measuring of the water evaporated by the meter, indicator diagrams of the engine were taken with a view to calculate the weights of steam by the ordinary method, and the calculations were found to agree with the meter; these calculations can be repeated and substantiated at any time. The second type of boiler tested was that of the ordinary steam-boat horizontal tubular boiler (fig. 4); the example chosen was one in a first-class ocean steamer; the temperature of the furnace was found to be 3200°, and the inside of the funnel about 1100°. The heating surface of this boiler was 22 feet per nominal horse-power, and the water evaporated about 8½ lbs. per pound of coal, according to the calculation from the diagrams. The coal consumed was about 20 lbs. per square foot of fire-grate, of the best Glasgow coal.

Fig. 6.



The next example taken was that of a first-class vertical tubular boiler (fig. 5), on Mr. David Napier's principle, now universally selected on the Clyde for river steamers. This boiler had a surface of about 22 feet per nominal horse-power; the temperature of the fire was found to be about 3300°, and in the funnel 1160°; the weight of water evaporated was found by calculation to be 8¾ lbs. per pound of coal consumed, and the weight of combustion about twenty pounds square foot of fire-grate. In the spiral boiler (fig. 6) of the 'San Carlos,' 'Guayaquil,' and 'Prinz van Orange' the boilers were found to give the following peculiar results:—first, that even with Scotch coal there was no smoke emitted from the chimney, and no carelessness on the part of the fireman seemed to occasion the formation of smoke; second, that the boilers showed a bright furnace, indicating first-class draught; the temperature of the funnel was found to be 480°, whilst the fire was at its greatest energy. The heating surface was, in the case of the 'San Carlos' and 'Guayaquil,' 2200 square feet, the coal consumed 1400 lbs. per hour, and the water evaporated 11 lbs. per pound of coal consumed; the fire-grate contained about 76 square feet, and the rate of combustion about twenty pounds per square foot of fire-grate. The heating surface of the boiler was 18 feet per nominal horse-power; the coal consumed was Glasgow best steam coal. The stoke-hole was found to be remarkably cool, and the boiler, which was loaded to 52 lbs. on the square inch steam pressure, and tested to 150 lbs. on the square inch water pressure, was found to be perfectly tight. In the case of the 'San Carlos,' I may mention that that ship has now steamed about 20,000 miles, and the vessel has not been in any one port more than three days; during that time she has been consuming soft Chili coal for a considerable part of her voyage, and the merits of the long flue show a decided advantage in this boiler over the ordinary tubular boiler for the native bituminous coal of South America.

In order to give a more extended form of the comparative evaporative power of various flues and tubular boilers, the writer begs to lay before this Association the accompanying Table. It shows several proportions of heating surface and evaporative powers of several ships that have come under his notice. He can certify the accuracy of most of these particulars, except that shown in the last column, which is taken from Professor Rankine's report on the performance of the 'Thetis.' This vessel has about six times more heating surface in her boilers in proportion to the coal consumed, than any example the writer is aware of. The boiler is Craddock's patent boiler, though that inventor's name appears rarely to be mentioned in connexion with the said vessel. Efficient, however, as this boiler must be as an evaporator, it cannot possibly accomplish the quantity shown in this Table.

The theoretical quantity of water capable of being heated from 90°, and evaporated at, say 212°, with an infinite quantity of heating surface and a perfect fire, is somewhere about 13½ lbs. per pound of coal; whilst from the diagrams represented in Professor Rankine's report of the 'Thetis' performance, 18 lbs. weight appear to be about the quantity of water per pound of coal. This calculation I have made from the diagrams published, and any party interested may repeat the calculations.

The calculation is made as follows: the area of the large cylinder, as shown in the diagram, is 1380 square inches, or 9·583 square feet. The four revolutions of piston marked on the diagram 49½, 52, 53, and 52 revolutions per minute, with a stroke of 2½ feet, or say 258·12 feet per minute, gives $258{\cdot}12 \times 9{\cdot}583 \times 60 = 146433$ cubic feet per hour. And if we take the average pressure shown in the four diagrams at the end of the piston stroke, supposing the barometer to be 14·5 lbs., we find the weight of that steam to be about 44 cubic feet per pound: this number therefore, divided by 44, gives the quantity of steam as 3300 pounds per hour; to this must be added $\frac{1}{20}$ for contents of ports and clearance, which makes 3465 pounds of steam.

This clearly gives the weight of the steam per hour given out of the cylinders after the work is performed, to this therefore must be added the quantity of heat that must have disappeared during the performance of the work; this, in the case of the 'Thetis,' is about $\frac{1}{5}$ of the entire heat; we must therefore add $\frac{1}{5}$, or say $3465 + 693 = 4158$ pounds of water must have been raised from a temperature of about 100° and evaporated, or say 18 lbs. of water to the pound of coal said to be consumed; this result is about equal to 20 lbs of water evaporated at 212°, to the pound of coal consumed; a quantity quite absurd.

Comparisons of certain Results obtained fram Certified Diagrams of Steamers 'Elk,' 'Earl of Aberdeen,' 'Valparaiso,' 'Pride of Erin,' 'Inka,' 'Europa,' 'Cambrian,' and 'Thetis.'

	Elk.	Earl of Aberdeen.	Valparaiso.	Pride of Erin.	Inka.	Europa.	Cambrian.	Thetis.
Nominal H.P.	250	380	320	400	80	648	472	80
Indicated ditto	780	780	826	960	272	1207	1072	226
Proportion of indicated H.P. to nominal H.P.	3·28	2·05	2·581	2·4	3·8	1·863	2·272	2·82
Diameter of Cylinder...	57in.	7 0in.	Two 52 Two 90	72	Two 28 Two 48	90	77·5	One 21 One 42
Length of Stroke	5 ft. 6 in.	6ft.	5ft.	5ft.6in.	3ft.	8ft.	7ft. 6in.	2ft. 6in.
Number of Strokes per minute..................	25	17·5	24	22	32	15½	16	52
Boilers, Flue or Tubular	Tubular.	Flue.	Flue.	Flue.	Flue.	Flue.	Flue.	Craddock's Patent.
Area of Fire-grate	144ft.	190ft.	130ft.	252	50	314	247	
Area of Heating Surface	4000	4300	2400	4400	480	7000	5400	About 4000
Coals consumed per hr.	3360lbs.	3584	2520	4928	672	5100	4480	226
Quality of Coal	Glasgow best.	Newcastle.	Welsh.	Welsh.	Welsh.	Welsh.	Welsh.	Good.
Steam evaporated per lb. of Coal	7·354	6·87	7·74	7·159	8·1	7·7	7·509	15 lbs. about.
Estimate, water evaporated	8·1	7·4	8·6	7·9	9·0	8·5	8·3	18lbs.
Coal consumption per indicated H.P..........	4·071	4·358	3·05	5·126	2·47	4·2	4·17	1·018
Fire-grate per nominal H.P......................	·576	·5	·406	·63	·625	·484	·536	

It therefore appears that in the report referred to, the indicated power of the said diagrams may be correct, but the coals said to be consumed per indicated horsepower per hour, namely 1·08, must be wrong; and before a proper comparison could be established between the merits of the 'Thetis'' boiler and that of any other boiler, a correct trial of the former would be necessary. In the mean time we have but to consider that the report of Professor Rankine was based upon one hour's consumption of say 230 lbs. of coal, and compare that with a mass of boiler, water and firebrick, weighing 20 tons, at a temperature of say 300°, it is evident that the mass of heat in proportion to the coal consumed is so great, that no conclusion should be made from such an experiment; also, that when the quantity of coal said to be consumed, viz. 230 lbs., is compared with area of fire-grate, say 40 square feet, it is evident that the result should not be depended upon, as no ordinary comparisons could be made of the condition of the fires before and after the experiment. In conclusion, let me ask of every party present to consider the trial trips of steam-ships and boilers in their true lights, and before drawing any inferences from such short trials, make a perusal of results obtained from sea voyages. The evaporative power and economy of boilers is one of the most important subjects for this Society to consider. We need only refer to the able Report drawn up by the Steam Shipping Committee of the British Association, to show how mixed up the question of the relative efficiency of the boiler and engines is generally considered. Indeed the American navy returns form the only reports showing the evaporative power of the boilers in this list, and the whole merit of a good evaporating boiler is often sacrificed to the character of the engines. With regard to the 'Thetis,' I would recommend any mistake to be remedied as soon as possible, as there are many contracts, involving much responsibility, formed in consequence of this report, that will lead to serious loss and disappointment to the steam-shipping interest, and the engineering profession of this country.

On the Density of Saturated Steam, and on the Law of Expansion of Superheated Steam. By WILLIAM FAIRBAIRN, *LL.D., F.R.S. &c.*

This paper contained a continuation of the experiments detailed in a paper read by Mr. Fairbairn at the Aberdeen Meeting, and which had been carried on in conjunction with Mr. Tate. Experimental determinations had been obtained of the density of steam fully confirming the anticipations of Mr. Thomson and Mr. Rankine, that the vapour of water does not exactly obey the gaseous laws. They show that the density of saturated steam is always greater than that given by the gaseous laws, even for temperatures as low as 136° Fahr., and at pressures below that of the atmosphere. The experiments at present extend over a range of temperature from 136° Fahr. to 292°, or from 2·6 to 60 lbs. pressure per square inch. The general result obtained is expressed in the following formulæ, which closely agrees with the experiments,

$$v=25{\cdot}62+\frac{49513}{P-{\cdot}72}, \quad \ldots\ldots\ldots\ldots \quad (1.)$$

$$P=\frac{49513}{v-25{\cdot}62}-0{\cdot}72 \quad \ldots\ldots\ldots\ldots \quad (2.)$$

where v is the specific volume or ratio of the volume of the steam to that of the water which produced it, at the pressure P, expressed in inches of mercury.

On the subject of superheating steam, the experiments throw some light, which the author hopes to follow up by a special series of experiments. They show that within a short distance of the maximum temperature of saturation the rate of expansion is variable, being higher than that of a perfect gas near the saturation point, and rapidly decreasing, till at a point at no great distance above the temperature of saturation it becomes sensibly identical with that of a perfect gas.

On an Atmospheric Washing Machine. By JOHN FISHER.

The action of this machine was derived from streams of air forced through the water from below. The author in his paper observed, that for effectual use the water must never be of a higher temperature than 140° of Fahrenheit. It was stated that machines on this principle, driven by steam-power, had been for some time past in successful operation for cleansing the soiled laces at Messrs. Fishers' manufactory at Nottingham.

On Giffard's Injector for Feeding Boilers. *By* William Froude.

In this instrument a jet of steam taken from the boiler and issuing from a properly tapered orifice, is met by and enveloped in a regulated supply of water, either cold or of limited temperature.

The column formed by the combination of water and steam is made to impinge on the aperture of a similarly tapered orifice, of rather smaller area, connected with the feed-pipe; and penetrating this orifice, it flows in a continuous stream into the boiler.

The rationale seems to be as follows:—were it possible to condense such a jet of steam by a simple abstraction of temperature, it would collapse into a jet of water having only $\frac{1}{1700}$th of its previous sectional area, its particles, however, retaining the same weight and velocity, and therefore the same momentum for each unit of time which they had possessed as steam. And since the momentum of a jet is the exact dynamic equivalent of the pressure which produces it, this water-jet would possess a momentum equal to that of a jet of equal diameter taken from a boiler having 1700 times the pressure of that from which itself had issued as steam, and would be capable of penetrating a boiler having a pressure enlarged almost in the same proportion.

In the injector the water which is added condenses the steam and becomes incorporated with it, forming a compound jet which possesses for each unit of time the same momentum which the jet of steam possessed. And if the supply of water be duly regulated, the sectional area of the compound jet may be precisely adapted to the orifice of the feed-pipe.

Now were that orifice equal in area to the steam-jet orifice, and were a jet of water allowed to issue from it under the same pressure which discharged the steam, the water-jet would have the same momentum for each unit of time as the steam-jet had, and therefore as the compound jet derived from it; and the two would precisely neutralize one another when brought into opposition. If, however, the steam-jet orifice be the larger of the two, then the jet derived from it, if reduced by condensation to the diameter of the smaller, will be the stronger in the same proportion, since it will possess the momentum due to the larger area of pressure; it will therefore drive back the water which is striving to escape from the feed-pipe, and will pass as a continuous stream into the boiler.

The water supply is considered to be correctly adjusted when the passage takes place without an overflow of steam or water; but the test is deceptive; for an overflow of steam merely implies that the supply of water is barely sufficient to condense the steam into a jet as small in section as the feed-pipe orifice; an overflow of water merely implies that though the steam is fully condensed, the supply of water has enlarged the compound jet to a section exceeding that of the feed-pipe orifice.

In reality the operation should be brought as near as possible to the latter limit; for though it will indeed seem to be proceeding quietly and properly in all the intermediate stages, it will be found that the compound jet, when not so enlarged as to fill the feed-pipe orifice, possessing its full momentum in a smaller section, will have energy enough to take up with it and carry into the boiler a considerable quantity of air, wasting thus not only its own power, but in a high degree that of the engine also, when it is a condensing one, since it encumbers the air-pump with extra duty.

On a Process for covering Submarine Wires with India-rubber for Telegraphic purposes. *By* Walter Hall.

The author exhibited a model of his machine, which effected the object by winding strips of rubber, and moistening the same with naphtha during the process of covering; the wire thus formed being covered with a thread of vulcanized India-rubber, and the whole afterwards subjected to a temperature of 140°. The wires thus covered were protected with a plaited covering of hempen cord, into which longitudinal steel wires were introduced for the purpose of giving strength.

Suggestions relative to Inland Navigation.

By Professor Hennessy, *F.R.S.*

The fact that the forces operating in canal and river navigation are so different from those of sea navigation, shows that a totally different construction may be adopted for the vessels employed. The short heavy barges with clumsily rounded bows and broad sterns should be entirely abandoned. Boats of very great length, compared to their breadth of beam, may be used for canals with considerable economy of power in proportion to the cargo. The highest perfection of lines may thus be attained so as to secure the smallest amount of resistance to motion, and the least disturbing effect to the canal banks. For this object also a selection might be made among the varieties of the screw propeller, which would obviate any lateral disturbance of the water and drive it backwards rather than sideways. In some cases the above suggestion as to the shape of boats could not be realized without lengthening locks, and wherever these are numerous, jointed vessels, like those proposed for the Indian rivers, might be employed. The loss of water in passing locks would be the same as for a train of entirely separate boats, while the resistance to propulsion would be considerably less. Steam-propelled boats thus constructed would probably realize the twofold result of economy in power and increase of speed to the highest limit advisable for traffic in heavy goods.

On the Longitudinal Stress of the Plate Girder. *By* CALCOTT REILLY.

On Suggestions for an Electro-Magnetic Railway Break. *By* Dr. B. W. RICHARDSON.

On the Character and Comparative Value of Gutta Percha and India-rubber employed as Insulators for Subaqueous Telegraphic Wires. *By* S. W. SILVER.

After pointing out some of the mistakes prevalent on the subject of the insulating properties of india-rubber, a comparison was made by the writer between the relative advantages and the insulating power of india-rubber and gutta percha respectively. Insulation in the case of a submarine cable depends upon two causes or properties of the bodies used:—1. The specific non-conducting power of the substance; 2. its impermeability, by which the original insulating conditions may be maintained. The insulating power of gutta percha is very high; but, in the case of a submarine telegraph cable, its porosity renders it a very imperfect insulator in practice. India-rubber, with lower *specific* insulating properties (as would appear from experiments made in dry air), is, nevertheless, practically a far more efficient insulator, by reason of its complete impermeability, while in addition it possesses a lower inductive capacity. It was pointed out that impermeability is as important a question as specific non-conductility in an insulator of such cables; and that even if a substance could be found insulating perfectly in dry air, it still might in practice be of questionable utility for submarine lines, owing to its porosity, as was the case with gutta percha. There was now no difficulty in covering wires with india-rubber.

On Improvements in Iron Ship-building. *By* W. SIMONS.

Diagonal Beams.—Each range of beams is placed in the reverse diagonal direction to the range of beams, above or below it, so that collectively the vessel's beams constitute a complete system of horizontal diagonal trussing.

Fore and aft along the middle of each range of beams are riveted strong iron clamps; and along the centre of the 'tween decks are secured in long lengths along the inside of the frames, strong, angle, back-to-back iron clamps. For these beams, various degrees of obliquity may be adopted; but the angle chosen by the author (represented in a plan which was exhibited) will probably best answer the combined purpose of a beam and diagonal truss.

It is a well known fact that the beams, as at present placed, do not prevent the straining of a vessel, but merely form a connexion between the vessel's sides and a framework to support the deck.

The hatchways and mast partners are framed in the usual manner, and the masts are wedged on both the upper and lower decks.

The decks may be laid also diagonally in a reverse direction to the beams, and may be edge-bolted throughout and made of hard wood.

This system of decks, by which the objectional butts are entirely avoided, is more particularly adapted for 4 or 5-decked battle-ships, where the strain from the weight of the guns and action of propeller is found to strain and twist them so much.

Iron Waterways are formed in the following manner. Every iron beam is made with a vertical projection on its upper edge at both ends; this projection is about 7 inches deep and 20 to 40 inches broad, according to the tonnage of the vessel. On the upper edge of these projections are riveted double-angle iron. On the front or bosom of these projections is riveted, in long lengths along the beams, heavy angle-iron, say 6+5. Over this are then placed the plates which form the waterway; these are rounded over on their inside edge, which is riveted to the heavy angle-iron inside; the top of the plate is double riveted down to the double angle-iron on each beam end: the outer edge is riveted to the angle-iron along the sheer strake, where it is securely iron-caulked.

Round any angle-iron frames necessary to project through the waterway is fitted exactly a doubling piece, which is securely caulked round the frame.

The usual iron stringer and wood water-ways are thus superseded, and this iron water-way, it is submitted, forms a serviceable and complete box gunwale.

The beam-end projections form also stronger and improved knee fastenings, particularly to the upper part of the beam, where hitherto in iron vessels such a knee has not yet been adopted, although considered essential in timber vessels.

In fact, for the convenience of stowage and passengers' berths, the knee or the under side of all iron beams on this principle might be dispensed with. Of course, this waterway can be adopted with either diagonal beams or common beams.

Plating diagonally with two thicknesses of plate, each in the reverse diagonal direction to the other, or with one thickness in combination with frames arranged in the reverse diagonal direction.

In the former case, both thicknesses of plating will be riveted together, and the butts arranged to make shifts with each other; by this mode of construction the present vertical frames become unnecessary, and even the keel not essential. In place of these are substituted, in long lengths, internal longitudinal stringers, clamps and keelsons, about 5 feet asunder; these would have the advantage over the present internal longitudinal fastenings, of being fitted and secured directly to the skin of the fabric through which they may be fastened every 3 inches; by this system it is not requisite that the plate butts be more securely riveted than the rest of the external skin, as it will be evident that such a vessel could not break asunder at the butts or vertical joints like a postage-stamp, as was described in the case of many late wrecks of iron ships constructed on the present mode.

Timber vessels of 2000 tons have been planked on this principle with complet success.

Keelsons made in the following manner have greater strength as a backbone, and the necessary rigidity to receive the thrust of diagonal central hold stanchions or trusses. Every floor, or alternate floor, is made to project up in the middle in the form of a square. Round these projections are fixed angle-iron, to which the upper and side plates of the keelson are secured in the form of a box. Bilge and sister keelsons may be also formed on the same principle.

The keelson required by Lloyds for their highest classed iron vessel, has only four rivets to secure it to the top of each floor; consequently, when by accident the strength of the bottom is tested, these rivets of course break, leaving the strength of the floors and keelson as a backbone untested, while with the above improved keelson, the floors are so well fastened to the keelson, that they must break before the keelson will yield.

Diagonal Central Hold Stanchions or Trusses.—In place of the common vertical hold and 'tween-deck pillars or stanchions in two lengths at present in use in wood and iron vessels, most of which are made portable, and intended merely for the support of the deck, the inventor forms, from stem to stern, a range of diagonal trussing in bars of one length, the joint object of which is to strengthen he fabric and support the deck.

These trusses are placed to cross each other in a reverse diagonal direction, so as to resist either a tensional or compressive strain; they are made of 5 × 2 flat iron, are securely riveted above to every second or fourth upper deck-beam, and below, a butt on, and are secured to the upper side of the keelson. They are riveted together at their points of intersection, and where they cross the line of the old beams, a double central back-to-back 7 × 6 angle-iron clamp is riveted to every truss and beam. If desired, a similar angle-iron clamp may be riveted along at the junction of their upper extremities with deck beams.

The angle of these stanchions is about 60°, that being found best suited to the convenience of the hatch arrangement. The hatchways and masts can easily be left clear.

It is submitted, these stanchions form a central range of diagonal trussing at a part of a vessel requiring support, and which hitherto has not had such; they will be of great service in connecting together two strong frameworks, namely a vessel's bottom, and her upper deck platform. The writer also places the diagonal stanchion in athwartship direction; this he has found reduces vibration in steamers, besides clearing the screw-shaft. On these principles of construction, the writer's firm have nearly completed at Glasgow a 900-ton iron Indiaman, named 'The R. Mackenzie;' and he is glad to state that the result of such practice has more than realized the expectation formed from the theory; and respecting the element of expense, he finds that such a vessel costs £2000 less than a Thames or Mersey-built timber ship of the same size and class.

Plate Butt Frames.—In an iron vessel plated in the common manner, the writer uses butt-frames. In the place of the usual mode of securing the vertical joints of the external plating on an iron internal strop *between* the frames, they are secured *upon* a frame in the following manner. There is bent round the exterior of every alternate angle-iron frame, a long continuous plate of some breadth and thickness, as the ordinary butt-strop; this plate is punched before being fixed to the frame; the plate-butts or vertical joints are then arranged to be riveted only on this continuous butt-frame.

If longer outside plating be desired, every third frame may be constructed as a butt-frame.

If preferred, the continuous butt-strop may be placed between the frames, in one length, from keel to gunwale.

By either of these modes of securing the butts of common plates, no short butt-strops are required, and it is evident that a vessel having her butts or vertical joints so secured, is greatly increased in point of strength, and that there is little or no liability to break asunder at those points.

Ceiling.—For the purpose of increasing the strength of iron vessels, the ceiling from the bilge keelson up to the gunwale is made of angle-iron or flat iron in one length placed diagonally and from 12 in. to 10 ft. apart, tailing from the centre of the vessel to the extremities. The port side of a ship being reverse to the starboard side, these diagonal ceiling bars are riveted to the reverse angle-iron of every frame, and their extremities secured to the gunwale angle-iron and bilge keelson.

These iron ceiling side trusses, in conjunction with my central range of stanchion trussing, yield great strength without occupying space, and both can be adopted with advantage in timber vessels and in battle-ships. If preferred, these diagonal ceiling bars may be of wood in iron vessels.

Iron Masts.—The writer plates iron masts and spars diagonally from top to bottom, the plates winding round the entire length and riveted together. He also forms an iron mast of diagonal spiral lattice-work riveted together at their points of intersection.

If desired, such a mast may be stayed transversely in its interior throughout. The writer also fixes winches to iron masts, with their spindles through the sides of the mast, the aperture required for such spindles being compensated by an internal doubling plate.

War Ships.—Between the seams of the external planks of wood battle-ships exposed to shot, the writer inserts iron or steel plates, in thickness from $1\frac{1}{2}$ to 2 inches, and in breadth the entire thickness of the planks to which they are secured; these being in long lengths, are bolted vertically to the planks above and below them, and besides increasing the strength of the vessel, will form a resistance to shot or shell: they may be placed from 6 or 8 inches asunder.

In wood battle-ships, he also fastens along the interior sides of their gun decks, vertical iron plates, from 1¾ to 2½ inches thick, close secured and bolted through the side. Such are for the purpose of resisting the shot after it has spent its force in penetrating the external wood side.

For the same purpose, he places fore and aft along the interior of the gun decks of wood battle-ships, angled metal shields, the apex of each being in the centre line of the gun ports, and bolted there through the side of the ship: where the upper and lower edges of these shield plates join the beams above and below, they are strongly bolted to the beams and to each other.

In an iron battle-ship or ram, he builds the side of the hull above water and plates it with 2 or 2½-inch thick iron or steel. Outside of this he timbers, planks, fastens, and caulks the wood side of a battle-ship, not for the purpose of strength, but for a resisting medium, in which a common ball may spend its force before coming into contact with the internal angle-plated shields, which it is submitted will then turn aside the ball from penetrating into the interior.

These angled shields answer also for beam knees, the weight and cost of which may be dispensed with.

It is submitted, that owing to such angled shields, the reduced thickness of shield plates protected by the timber side, the diagonal arrangements of four tiers of beams, and the central diagonal trussings, an iron battle ram so constructed would have less displacement, greater strength, more buoyancy, greater speed, and be more creditable to the engineering science of this country than those now building at an expense of 1½ million, the designs of which were not thrown open to public competition, although the Exhibition building, St. George's Hall, and some of the first engineering structures in England, are the result of such a course.

A Novel Means to lessen the frightful Loss of Life round our exposed Coasts by rendering the Element itself an Inert Barrier against the Power of the Sea; also a Permanent Deep-water Harbour of Refuge by Artificial Bars. *By* Admiral TAYLOR.

On Street Railways as used in the United States, illustrated by a Model of a Tramway and Car, or Omnibus capable of conveying sixty persons. *By* G. F. TRAIN, *of Boston, U.S.A.*

In America such a car is drawn by a pair of horses. The tramway is laid in the centre of the street, and the rail is so shallow that it offers no obstruction whatever to carriages crossing it. In wide streets two such tracks are laid down, one for the going and the other for the returning traffic. Mr. T. stated that in the cities of America the system was in constant use, and was now an absolute necessity there. He saw no difficulty in carrying out the system in our English towns or in London. Where there were inclines, an extra horse would be used; and where a street was not wide enough for two tracks, he would put down a single track there, and bring the traffic back by a line laid in a parallel street. He had received a concession to bring out his system in Birkenhead, and he hoped by September to be able to show it in operation there. All he required was leave from the authorities in any town to lay down his trams and run his carriages.

On a Mode of covering Wires with India-rubber.
By Messrs. WERNER *and* C. W. SIEMENS.

The authors exhibited a very ingenious machine for accomplishing this object. These gentlemen use no solvent or heat whatever, but take advantage of the property which india-rubber possesses of forming a perfect junction when newly-cut surfaces are brought together under pressure. The core or wire, with the ribbon of rubber applied to it longitudinally, is pushed into an orifice, which serves as a guide to carry them into the machine, so that the superfluous rubber is cut off by what may be termed a revolving pair of scissors, formed by a disc of steel with a sharp edge revolving excentrically against a stationary plate, and immediately, by means of two grooved wheels, the edges are pressed together, and thus the wire becomes encased in a perfect tube of india-rubber. As many additional tubes as may be desired can be then put on. The machine is also applicable to the coating of wires with what is known as Wray's Compound, with vulcanized India-rubber and other compound substances containing India-rubber.

APPENDIX.

PHYSIOLOGY.

On the Deglutition of Alimentary Fluids.

By Professor J. H. CORBETT, *M.D.*

In this paper the author describes two distinct forms of deglutition; that while the alimentary bolus is propelled with rapidity over the epiglottis, fluids can flow in two streams, one at each side of the epiglottis and of the aryteno-epiglottic folds, without the danger incidental to its passage over the central aperture of the larynx. He believes that such occurs in the newly-born infant and mammal during suction; it can take place in the sipping of fluids, swallowing of the saliva, and even during drinking in a continuous draught. Ordinary drinking is accomplished by gentle muscular movements, which should not be confounded with the gulping of fluids. In gulping, the fluid is rapidly and forcibly propelled backwards through the isthmus of the fauces, each gulp requiring a separate act of deglutition; such act much resembles the deglutition of solids. The author contends that when the infant or mammal seizing and retaining the nipple, sucks in the fluid in an almost continuous stream, the process of respiration is not totally interrupted, as should occur if the fluid absolutely passed in the middle line over the epiglottis; it is argued that the salivary secretion is swallowed safely during sleep; fluid carefully introduced into the mouth of persons in a state of insensibility, passes into the pharynx; fluid poured gently into the mouth of a patient whose head rests upon one side, flows backwards by a gentle act of deglutition, which is chiefly performed in this instance by the muscles of the corresponding side; fluids cannot be shaped like solid food into a definite form; alimentary drinks must be subject, in their course, to the laws which regulate the passage of fluids in other cases; the root of the tongue being narrow and the organ convex on its upper surface, fluids must naturally have a tendency to flow from the middle line to either side; during the mastication of solid aliment, the juices expressed by the action of the teeth and pressure of the tongue, rapidly escape backwards, so that the bulk of the mass is considerably diminished before the deglutition of the solid part is attempted; during inflammatory affections of the tonsillitic glands, the swallowing of fluids is attended with difficulty, while a moderately sized portion of solid aliment, which proceeds in the middle line, may be transmitted with comparative facility; when a single gland is much inflamed, deglutition is chiefly performed at the opposite side.

In experiments made by the author on the dead body, fluid poured upon the dorsum of the tongue passes backwards into the pharynx in two streams, through the grooved channels situated at each side of the epiglottis and aryteno-epiglottic folds.

From all these considerations, it is inferred that in the living body, during the deglutition of fluids, the uvula falls forward upon the tongue in front of the epiglottis; thus both uvula and epiglottis afford protection to the respiratory apparatus. The fluid is divided by the uvula into two currents, which descend at each side of the root of the tongue, under the half arches of the palate, as water flows under the arches of a bridge; and such is the principal use of the uvula. The anatomical arrangements in the human body are perfectly adequate for the transmission of fluid in this safe manner. The anatomy of the porpoise, in which the larynx rises for several inches above the level of the tongue, affords a strong confirmation of this view, which is further sustained by instances in which the epiglottis has been destroyed, wounds of the throat, &c. The distinctness of the two forms of deglutition is also indicated by the fact that the mouth may be filled with food, and yet drink can be swallowed without displacement of the solid aliment; the newly-born infant can perform suction in a perfect manner; on the other hand, the power of swallowing solid food is gradually acquired, and the organs of deglutition are trained by successive steps to the safe performance of this process.

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Contents:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53;—James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Œconomy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations;—John P. Bell, M.D., Observations on the Character and Measurements of Degradation of the Yorkshire Coast; First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration;—Robert Mallet, Third Report on the Facts of Earthquake Phænomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s*.

Contents:—R. Mallet, Third Report on the Facts of Earthquake Phænomena (continued);—Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54;—Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s*.

Contents:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55;—Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-Registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

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Contents;—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and Neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof. Phillips, Report on Cleavage and Foliation in Rocks, and on the Theoretical Explanations of these Phænomena: Part I.;—Dr. T. Wright on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

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PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at 15s.*

CONTENTS:—A. Cayley, Report on the Recent Progress of Theoretical Dynamics;—Sixteenth and final Report of Committee on Experiments on the Growth and Vitality of Seeds;—James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-Power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall;—Dr. G. Plarr, De quelques Transformations de la Somme $\Sigma_0^{t\,-\alpha}\frac{a^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, a étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinasion de factorielles, la notation $a^{t|+1}$ désignant le produit des t facteurs $a\,(a+1)\,(a+2)$ &c....$(a+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—John P. Hodges, M.D., on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, C.E., on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Professor W. A. Miller, M.D., on Electro-Chemistry;—John Simpson, R.N., Results of Thermometrical Observations made at the 'Plover's' Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54;—Charles James Hargrave, LL.D., on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Professor James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, M.A., Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at 20s.*

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–58;—R. H. Meade, on some Points in the Anatomy of the Araneidea, or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the Collapse of Glass Globes and Cylinders;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Michael Connal and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857;—Report of the Committee on Shipping Statistics;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857-58;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India;—George C. Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr. Vignoles' paper "On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;"—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories;—R. Beckley, Description of a Self-recording Anemometer.

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PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at 15s.*

CONTENTS:—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—A. Thomson, Esq. of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahago, Lanarkshire;—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Breaks for Railway Trains;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858-59;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858-59;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c. &c.;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—G. C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren de la Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S.;—W. Fairbairn, The Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air;—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Prof. H. J. Stephen Smith, Report on the Theory of Numbers: Part I.;—Report of the Committee on Steam-ship performance;—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

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PLATES I., II., III.

Illustrative of Captain Maury's paper on the Climate of the Antarctic Regions, as indicated by observations upon the height of the Barometer, and direction of the Winds at Sea.

PLATES IV. to VIII.

Illustrative of the Rev. W. Vernon Harcourt's Report on the Effects of long-continued Heat, illustrative of Geological Phenomena.

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